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Investigating the Utilization of Mushrooms in Beef-Based Products for Improved Health

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INVESTIGATING THE UTILIZATION OF MUSHROOMS IN BEEF-BASED PRODUCTS FOR IMPROVED HEALTH

A Thesis Presented

By

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INVESTIGATING THE UTILIZATION OF MUSHROOMS IN BEEF-BASED PRODUCTS FOR IMPROVED HEALTH

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DEDICATION

To my parents for their constant love and support. Thank you for shaping me and motivating me to be the person I am today. I would not be here without you.

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ABSTRACT

INVESTIGATING THE UTILIZATION OF MUSHROOMS IN BEEF-BASED PRODUCTS FOR IMPROVED HEALTH

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This research investigated the use of mushrooms in beef-based products as a means to reduce overall sodium and fat for food service applications. Initial product development used physical characterization analysis (color, moisture, texture, yield, fat, and sodium) to determine initial threshold of mushroom inclusion with minimal differences against an all-meat control. Additional physical analysis then investigated a variety of other factors (mushroom type, blanching, mushroom particle size, salt level, and meat/fat blend) to determine if there were other attributing ingredient characteristics that would yield statistical similarity to the all-meat control. Taco filling formulations with optimized ingredients were then fielded in a hedonic sensory study to untrained consumers to evaluate attributes product (overall liking, aroma, color, flavor, juiciness, saltiness, and texture). Samples with liking scores that closely matched the control where then fielded in paired preference tests to determine acceptance using patrons from the UMass Dining Commons. Based on physical property assessments, an optimized taco filling formulation containing up to 45% un-blanched, white button mushrooms finely chopped (1 to 5 mm) maximized mushroom usage while minimizing differences from the all-meat control. Furthermore, consumers preferred a reduced sodium taco filling

containing 45% mushroom over a full sodium taco filling also containing 45% mushroom in a food service fielded paired preference sensory test.

The second part of this research investigated the use of mushrooms in burger patties in direct comparison to textured soy protein, which is a well established and used meat extender in the industry, specifically in reduced sodium applications. Again, initial product development used physical characterization analysis to determine initial thresholds of meat extender inclusion with minimal differences against an all-meat control. Optimized patty formulations were then fielded in two hedonic sensory studies to identify favorable meat extenders and concentrations of supplementation in full and reduced sodium patties. Results from the hedonic study showed that reduced sodium meat products extended with mushroom can be equally liked to all-meat full sodium counterparts. The findings from this research showed how mushroom has the potential to be successfully incorporated into meat products to lower sodium and fat without compromising consumer expectation and altering acceptance.

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LIST OF ABBREVIATIONS

ANOVA – Analysis of Variance

CDC – Centers for Disease Control and Prevention

CIA – Culinary Institute of America

IRB – Institutional Review Board

kPa – kilopascal

NIH – National Institutes of Health

RACC – Reference Amount Customarily Consumed

SIMS – Sensory Information Management System

CHAPTER 1

INTRODUCTION

Heart disease is the leading cause of death in the United States. This disease kills 610,000 people every year, which equates to 1 in every 4 deaths (Centers for Disease Control and Prevention, 2015). Although some risk factors such as age and family history cannot be controlled, people can put themselves at higher risk due to their lifestyle choices. Poor diet can lead to high blood pressure and high cholesterol levels which are major risk factors for heart disease with about half of Americans suffering from at least one of these factors (Fryar, Chen, & Li, 2012). Americans can take a proactive approach to combating heart disease by improving their eating habits.

Government organizations such as the National Institutes of Health (NIH) and Centers for Disease Control and Prevention (CDC) list foods and nutrients to avoid in efforts to inform consumers on how to lower their risk for chronic diseases. Two components that show up frequently on these lists are sodium and saturated fats, of which animal-based products are a major source. The 2010 Dietary Guidelines for Americans specifically cited sodium and saturated fats as “food components to decrease” and vegetables as one of the “foods and nutrients to increase” to shift eating habits away from meat-based products to more plant-based products (U.S. Department of Agriculture and U.S. Department of Health and Human Services, 2010). The guidelines state that the overconsumption of sodium can increase blood pressure, which can increase the risk of not only cardiovascular disease but also congestive heart failure and kidney disease. The guidelines also state that higher saturated fat intake is associated to higher total and lowdensity lipoprotein levels which have been shown to be risk factors for cardiovascular disease.

Although diet recommendations guided by scientific research are available to consumers, Americans continue to eat foods detrimental to their health. The average American consumes approximately 3,400 mg to 4,500 mg of sodium per day despite the daily recommendation of 2,300 mg or less (U.S. Department of Agriculture and U.S. Department of Health and Human Services, 2010). Sodium is added to foods primarily as salt, or sodium chloride, which can be used in multiple processes such as curing, baking, retaining moisture, and enhancing flavors. This versatility makes sodium abundant in many different types of foods. A major contributor of saturated fats is red meat. Although red meat intake has been a public health concern since the 1950s and intake has slowly declined over the last few decades, it remains the highest contributor to total meat consumption at 58% (Daniel, Cross, & Sinha, 2011). In the United States, where meat consumption is more than three times the global average, it is imperative to design meat products with decreased sodium and fat while still delivering acceptable taste in order to reduce the risk of heart disease.

CHAPTER 2

LITERATURE REVIEW

2.1 Functional Ingredients as Meat Extenders

A variety of ingredients have been studied as functional extenders in meat applications to reduce calories and fat content. Supplementing meat with extenders can also reduce product cost and improve nutritional content, which also makes this an advantageous strategy (Yusof & Babji, 1996; Abdel-Aziz, Esmail, Hussein, & Janssen, 1997). However, formulation of beef products with extenders to reduce fat content can reduce meat particle binding, alter product color, and reduce beef flavor (Brewer, 2012). Extenders can be placed into three general categories: protein-based, fat-based, and carbohydrate-based.

2.1.1 Protein-Based Meat Extenders

Proteins can be used for many functions in meat products due to their manipulative structure through pH, heat, or enzymatic denaturation. Proteins such as whey, soy, and collagen function as water binders, fat emulsifiers, and gel stabilizers as their polar and nonpolar regions provide unique functional properties (Kinsella, 1976; Brewer, 2012). Also, protein's ability to associate with fat and water results in products with increased cook yield and moisture content (Brewer, 2012).

Whey ingredients can come in different protein concentrations and since they are highly soluble in water, they can either be added as a powder or injected into muscle products with no drastic alteration to product processing (Chrystall, 1994; Szerman et al., 2007; Walsh et al., 2010; Brewer, 2012). Whey's bland flavor and flavor-binding capabilities also make it advantageous for meat extension (Brewer, 2012). Johnson

(2000) showed that although whey protein adds to the cost of extended meat products, the water retained offsets this.

Soy can come in a variety of forms such as flour, concentrate, or protein isolate with each having a different protein concentration (50%, 70%, and 90% respectively). Although soy supplementation has shown to increase moisture, tenderness, and yield, sensory studies have noted unfavorable flavor and texture changes (Kotula & Berry, 1986; Brewer, McKeith, & Britt, 1992; Ho, Wilson, & Sebranek, 1997). Studies from Akesowan (2010) and Danowska-Oziewicz (2014) have shown that soy protein isolate incorporated into pork patties at 3% and 2% by weight respectively resulted in decreased overall and meaty flavor scores and increased bean flavor. Also, textured soy protein substituted into ground beef patties at 15% and 30% by weight were more tender than their all-meat counterparts, but were perceived to have less meat flavor and lower overall flavor quality (Deliza, Saldivar, Germani, Benassi, & Cabral, 2002). Whey and soy are also known allergens and meat products containing these ingredients must abide by labeling regulations based on the amount added (Brewer, 2012).

2.1.2 Fat-Based Meat Extenders

Fat-based extenders, such as soy lecithin, can perform lipid-based functions in meat products without providing as many calories (Brewer, 2012). These extenders can be used as emulsifiers to keep ingredients suspended within meat products. Soy lecithin has shown to improve cook yield and texture in ground beef while reducing fat content from 25% to 10% (Youseff & Barbut, 2011). Although promising, the research on fat-based extenders is limited and not as extensive as other categories.

2.1.3 Carbohydrate-Based Meat Extenders

Carbohydrate-based extenders such as flours, starches, fibers, and gums are mainly used as fat mimetics. These extenders bind water, thicken, and form gels that can bind and release water to provide mouth feel similar to fat (Tomasik, 2004; Brewer, 2012). These functions result in products with increased yield and improved texture.

Flours, starches, and fibers have specifically been shown to increase cook yield by binding and retaining moisture through extensive research. Wheat germ flour, sorghum flour, and modified cornstarch have also shown to increase tenderness and juiciness of ground beef patties (Rocha-Garza & Zayas, 1995; Huang, Zayas, & Bowers, 1999; Khalil, 2000). Although physical characteristics of these patties improved, these ingredients also contribute unwanted wheat or cereal flavors that are undesirable in meat products. In addition, tapioca starch and oat fiber have been shown to affect beef flavor in beef patties by delaying the release of positive flavor components produced by the Maillard reaction (Chevance et al., 2000).

Finally, gums such as carrageenan, xanthan, locust bean, and guar gum increase water-holding capacity especially when used in combination with other carbohydrate-based extenders. Combinations of carrageenan with alginate or carrageenan, starch, and phosphate added to beef patties resulted in similar or increased yield when compared to their all-meat counterparts (Lin & Keeton, 1998; Brewer, McKeith, & Britt, 1992). Low-fat frankfurters with the addition of carrageenan and xanthan gum had increased yield and decreased hardness, springiness, and chewiness compared to the full fat control (Mittal & Barbut, 1994). This research has shown that a variety of hydrocolloids can be incorporated into meat products, however each has its own set of advantages and disadvantages.

2.2 Using Mushrooms as Meat Extenders

Mushrooms have the potential of being healthy meat extenders due to their low fat and sodium contents, 5.00 mg/100 g and 0.34 g/100 g respectively, as well as providing umami flavor (Raw white mushroom, USDA National Nutrient Database, 2016; Phat, Moon, & Lee, 2016). Research has been conducted on different types of mushroom replacements into various meat-based products.

In 2011, Wan Rosli and coworkers (2011) incorporated blanched oyster mushrooms into chicken patties at 25% and 50% by weight. The addition of mushrooms significantly decreased lightness (L*) and yellow color (b*) of the patties while maintaining a similar red color (a*). The results of the study also showed that patties containing the mushrooms had similar cook yield and moisture retention compared to the all-meat control. A Texture Profile Analysis determined that the mushrooms made patties significantly hard, cohesive, gummy, and chewy than their all-meat counterparts. A follow-up study, conducted by Wan Rosli and Solihah (2014), subjected the same chicken patty formulations, again containing oyster mushrooms at 25% and 50% by weight, to hedonic sensory testing where aroma, color, springiness, juiciness, flavor, and overall acceptance were evaluated. The liking scores for the oyster mushroom patties and the all-meat control patties did not significantly differ for all attributes. Wan Rosli also conducted a similar physiochemical and sensory analysis on beef patties containing oyster mushrooms at the same substitution levels of 25% and 50% by weight (Wan Rosli & Solihah, 2012). As mushroom substitution increased, cook yield and moisture retention decreased for beef patties, however these attributes stayed constant in chicken patties. Similar to the chicken patty work, sensory evaluation showed that beef patties with the addition of mushroom scored similar liking across all attributes compared to the all-meat control. This set of studies from Wan Rosli showed that even though mushroom substitution into meat patties altered certain physiochemical attributes, these differences did not alter consumer likability during sensory evaluation.

Cha and coworkers (2014) also conducted a physiochemical and sensory analysis but on pork patties supplemented with ground, white jelly mushrooms at 10%, 20%, and 30% by weight. White jelly mushroom was selected due to its bioactive properties and oil binding capacity. The addition of mushrooms improved cook yield and oil binding capacity within the patties, while slight increases in lightness and yellow color were detected. Sensory results showed mushroom substitution up to 30% did not affect the liking of patty appearance, color, flavor, or texture. However the formulation containing 10% white jelly mushroom was the only formula deemed more acceptable overall than the all-meat control.

Current research shows that mushrooms can be promising meat extenders to improve quality or nutritional content. Myrdal Miller and coworkers (2014) extended this research by using sautéed, ground white button mushrooms at 50% and 80% substitution by weight to investigate the flavor-enhancing properties of mushroom in reduced-salt taco filling. Results from the trained quantitative, descriptive panel showed that taco filling with 80% mushrooms and 25% less salt still received similar flavor intensity scores as the all-meat, full salt control. This finding indicates that 50% and even 80% substitution with mushrooms can maintain flavor even with less salt.

CHAPTER 3

UTILIZING MUSHROOMS TO REDUCE OVERALL SODIUM IN TACO FILLING USING PHYSICAL AND SENSORY EVALUATION

3.1 Introduction

The work of Myrdal Miller and coworkers suggested that mushrooms might be more advantageous than other meat extenders since their umami properties could be utilized in low sodium products. However, additional research is needed to further elucidate how mushroom type and processing impacts the ability to produce ground meat products with reduced sodium. Therefore, the objective of this research was to investigate reduced sodium taco fillings with mushrooms at various particle sizes with and without blanching on both physical properties and consumer acceptance in order to optimize mushrooms as an ingredient that can make the most sensory acceptable and healthiest meat products possible.

3.2 Materials and Methods

3.2.1 Mushroom and Beef Preparation

White button (immature *Agaricus bisporus*) and portobello mushrooms (mature *Agaricus bisporus*) were supplied by Giorgio Foods (Blandon, PA, U.S.A.). White button mushrooms came as 6.35mm slices and portobello mushrooms ranging from 57.2 mm to 108 mm were quartered before preparation. Ground beef (80/20 lean fat blend) was supplied by Arnold's Meats (Chicopee, MA, U.S.A.). The Culinary Institute of America (CIA) provided the all-meat taco filling and spice blend recipes (Table 1). All spices were purchased from a local retailer. Mushrooms that required blanching were placed in a digital steamer (Hamilton Beach Brands Inc., Southern Pines, NC, U.S.A.) for 9 minutes at 90˚C, which has been shown to inactivate the browning enzyme polyphenoloxidase (Devece et al., 1999).

Table 1. All-meat taco filling recipe, raw weight. Note: Weight percentages for mushroom substitution were taken out of the "Ground Beef" portion of the recipe for formulations requiring mushrooms.

Ingredient	% Weight
Ground Beef	70.18
Diced Onion	16.23
Tomato Paste	3.25
Water	3.25
Canola Oil	2.16
Finely Chopped Garlic	1.52
Salt	0.97
Chili Powder	0.81
Ground Cumin	0.68
Paprika	0.33
Onion Powder	0.22
Garlic Powder	0.19
Black Pepper	0.06
Sugar	0.06
Mexican Oregano	0.05
Cayenne	0.03

Blanched and non-blanched mushrooms were placed into a food processor (Cuisinart, East Windsor, NJ, U.S.A.) for 6 one-second pulses to obtain small particulate (1 to 5 mm) or 2 one-second pulses to obtain large particulate (5 to 10 mm). Mushrooms were not pushed into the blade in between pulses. Particulate larger than the desired size range was removed with a sieve after chopping. Sieves with 6 mm and 10 mm hole sizes were used for the small and large particulate respectively. These chopping protocols were established with preliminary particle size distribution tests to confirm that chopping times would result in particles falling within the desired size range. Preliminary size distribution tests used a mechanical sieve shaker with 203 mm diameter sieves ranging in sieve hole sizes of 2 to 10 mm (Thermo Fischer Scientific, Waltham, MA, U.S.A.) to separate chopped mushroom into fractions based on AOAC Method 973.03. Established protocols yielded 95% to 99% of particulate in the desired size range.

3.2.2 Preparation for Physical Testing

Initial tests on ground beef-mushroom blends were conducted by cooking varying ratios of ground beef and prepared mushroom (Table 2) in a 305 mm diameter aluminum frying pan (Pedrini, Lifetime Brands, Garden City, NY, U.S.A.) on an electric range (Kenmore 94173, Kenmore, Chicago, IL, U.S.A.). Formulations were cooked at medium high heat until the internal temperature reached 74˚C, which took between 10 to 15 minutes. Internal temperature was taken by leveling out the formulation in the pan and inserting a temperature probe (Thermo Fischer Scientific, Waltham, MA, U.S.A.) at an angle making sure the tip was in the middle of the formula and did not touch the pan. Temperatures were measured at three different locations in the pan.

Table 2. Ground beef and mushroom weights for sample formulation for each set of physical tests.

Mushroom Concentration (% Weight)	Weight of Mushroom (g)	Weight of Ground Beef (g)
Mushroom Concentration Optimization (Physical Test Set #1)		
0	0.0	1056.0
25	264.0	792.0
50	528.0	528.0
75	792.0	264.0
100	1056.0	0.0
Mushroom Type, Blanching, Size, and Concentration Optimization (Physical Test Set #2)		
0	0.0	1056.0
15	158.4	897.6
30	316.8	739.2
45	475.2	580.8

3.2.3 Cook Yield Test

Cook yield was determined by measuring the weight of each formulation before and after cooking in addition to a third weight measurement after the cooking liquid was removed. Formulations were drained through a 203 mm diameter by 50.8 mm height U.S. Standard No. 10 sieve (Thermo Fischer Scientific, Waltham, MA, U.S.A.). Cook yield with and without cooking liquid was calculated with the following equation and the results were reported as percentages (Wan Rosli, Solihah, Aishah, Nik Farkurudin, & Mohsin, 2011): Cook Yield (%) = (Cooked Weight/Pre-Cooked Weight) * 100.

3.2.4 Moisture Content Test

Moisture content was measured (AOAC Method 950.46 A) by placing 2 ± 0.01 grams of drained sample in a 57.2 mm diameter aluminum, weighing dish (Scientific Equipment of Houston, Navasota, TX, U.S.A.) and placed in a vacuum oven (Lab-Lane Instruments, Melrose Park, IL) connected to a rotary vacuum pump (FJC, Mooresville, NC, U.S.A.). Oven temperature was 100°C and pressure was 100 mm Hg. Drying was conducted until the weight of the samples was constant. Results were reported as percent moisture.

3.2.5 Color Analysis

Color measurements of samples were determined using a colorimeter (ColorFlex EZ™, Hunter Lab, Reston, VA, U.S.A.) on the L*a*b* scale. A sample of formulation was placed in a glass sample cup and covered with a white foam board background. The instrument was calibrated with a white Illuminant D65 10° Observer ASTM E308: X: 79.59, Y: 84.44, and Z: 87.25 standard. Results were reported without units.

3.2.6 Texture Analysis

Texture analysis was executed using an imperfect squeezing flow viscosimetry method as a test to evaluate the rigidity of each formulation (Suwonsichon & Peleg, 1999). A sample of formulation was filled to the top of a circular Teflon™ dish (140 mm diameter and 20 mm in depth) and compressed with a circular Teflon™ probe (100 mm diameter) at a speed of 5 mm/second. Initial sample height was set at 20 mm and compressed to a final height of 10 mm. The compression was held for 120 seconds. Two metrics were recorded for evaluation: maximum stress and post-compression, or residual stress. Results were reported in kilopascals (kPa).

3.2.7 Sodium Analysis

Sodium content analysis was executed using an ion selective electrode based on AOAC Method 976.25. Results were reported in milligrams of sodium per gram of sample. The following concentrations were used when the potential effects of salt on ground beef and mushroom formulations were determined: 0.53%, 0.68%, 0.82%, and 0.97% by weight. The full salt control formulation had a concentration of 0.97% (Table 1) while 0.82%, 0.68%, and 0.53% equaled 15%, 30%, and 45% reductions from the control respectively.

3.2.8 Culinary Application for Sensory Testing

Taco filling preparation followed the recipe provided by the CIA (Table 1). The onions, chopped to an approximately 8 mm dice, and garlic, chopped to an approximately 3 mm dice, were sautéed in canola oil over medium high heat using an electric range for 2 minutes. The spice blend was then added and cooked for an additional 3 minutes. The tomato paste, ground beef, mushrooms, and salt were then added and cooked until the internal temperature reached 74˚C taking approximately 15 to 20 minutes. Cooked formulations were kept at temperatures over 60˚C, to avoid potential foodborne illness, in chafing dishes before being served. Formulas were not drained prior to serving.

3.2.9 Hedonic Sensory Test

One hedonic preference test was fielded at the UMass Food Science Chenoweth Laboratory following a sequential, monadic test method. Approval from the University of Massachusetts Institutional Review Board (IRB) for the Protection of Human Subjects was obtained prior to fielding these experiments (Protocol ID 2014-2180). Test subjects were seated at isolation stations to provide a consistent test environment and reduce bias from the presence of other participants. Untrained students from the campus were recruited for the test (N=55). The test was set up in a block design, designed with Sensory Information Management System (SIMS) 2000 software Version 6.0 (Sensory Computer Systems LLC, Berkeley Heights, NJ, U.S.A.), with each of the test subjects randomly evaluating the 4 of the 7 tested formulations to reduce palate fatigue. Each test subject was given 50-gram samples of the control and 3 variant formulations in 59 mL plastic portion cups served at 66˚C to 71˚C with water and unsalted crackers. Next, test subjects used a ballot to evaluate each of the samples on a 9-point hedonic scale (1=extremely dislike, 5=neutral, and 9=extremely like) (Peryam & Pilgrim, 1957). The attributes evaluated during this test were selected based on their effect on consumer perception and preference: overall liking, aroma, color, flavor, juiciness, saltiness, and texture.

3.2.10 Paired Preference Sensory Test

Two paired preference tests were fielded at the UMass Dining Commons. Approval from the University of Massachusetts IRB for the Protection of Human Subjects was obtained prior to fielding these experiments (Protocol ID 2014-2180). The paired preference test was selected due to its simple design, flexible sample presentation, and clear results (Lawless & Heymann, 2010). The test design used sequential sample presentation due to the heterogeneity within and between taco filling formulations (ASTM Method E2263 – 12). Test subjects were seated at isolation stations to provide a consistent test environment and reduce bias from the presence of other participants. Untrained dining commons patrons were recruited for the two tests (N=159 and N=158 respectively). Each test subject received 50-gram samples of each formulation, in a randomized order designed by the SIMS 2000, in 59 mL plastic portion cups served at 66˚C to 71˚C with water and unsalted crackers. Next, test subjects filled out a provided ballot to select which formulation they preferred and also wrote comments on the reasoning behind their selection. Finally, test subjects completed a second ballot asking information about their gender, age, and willingness to consume other products (meat-based, meat-alternative, vegetarian, and mushroom).

3.2.11 Statistical Analysis

Three replications of two measures were conducted on each formulation for each of the physical analyses. The order of analysis for each variant formulation was randomized to reduce order bias. The data from the physical analyses was evaluated using analysis of variance (ANOVA) and Dunnett's Test with SAS 9.4 Windows version 6.1.7601 (SAS Institute Inc., Cary, NC, U.S.A.). The ANOVA was selected to identify the presence of a difference amongst the variant formulations and the all-meat control for each physical test, however due to the limitations of the ANOVA it could not determine if or how many variant formulations significantly differed from the all-meat control. When significant differences were found using the ANOVA, the Dunnett's Test was conducted to directly compare each variant formulation to the all-meat control and identify specific, significant differences. The ANOVA main effects for the first set of physical tests focusing on the optimization of mushroom concentration were "mushroom concentration" and "replication". The all-meat control (0% mushroom concentration) was included in this analysis. Each variant formulation and the all-meat control were analyzed as "treatments" for the Dunnett's Test. The ANOVA main effects for the second set of physical tests focusing on the optimization of mushroom type, blanching, size, and concentration were "mushroom type", "mushroom blanching", "mushroom particle size", "mushroom concentration", and "replication". Only a single all-meat control (0% mushroom concentration) underwent physical analysis independent of the other mushroom concentrations and was inadvertently left out of the ANOVA. However, the all-meat control was reintroduced in the Dunnett's Test to identify significant differences between the all-meat control and each variant formulation, or "treatment".

Data from the hedonic sensory study was also evaluated using an ANOVA to identify a difference in liking scores amongst the variant formulations and the all-meat control. Further data analysis with Duncan's New Multiple Range Test was conducted to compare the liking scores of the variant formulations not only to the all-meat control but also to each other. This test was selected to detect differences in liking from the all-meat control as well as identifying any thresholds in liking across a range of mushroom concentrations and salt contents.

Data from the paired preference studies was analyzed by calculating a Z-score and comparing that value to the two-tailed Z-score of 1.96 for $\alpha = 0.05$. Test Z-scores larger than 1.96 indicated a statistically significant preference of one formulation over the other (Lawless & Heymann, 2010).

3.3 Results and Discussion

3.3.1 Optimization of Mushroom Concentration in Taco Filling

The initial set of physical tests was conducted to identify the formulation with the highest possible mushroom concentration that still resembled the all-meat control. Mushroom type, preparation, and particle size was kept consistent throughout all formulations to solely focus on the effect of mushroom concentration on the physical characteristics. All formulations contained non-blanched white button mushrooms chopped to a small particle size at concentrations ranging from 0% to 100% by weight.

Table 3. Physical analysis of ground beef formulations with varying mushroom concentration on a percent weight basis. Note: Mean±SD for triplicate determinations. Values with an * indicate a significant difference of a variant formulation from the all-meat control (0% mushroom) within a row (Dunnett, P=0.05).

Parameter	Ground beef and mushroom formulations				
	0% mushroom	25% mushroom	50% mushroom	75% mushroom	100% mushroom
Physical Composition (%)					
Moisture content	61.3±0.88	65.3*±1.4	71.8*±2.2	79.9*±1.2	90.5*±0.90
Cook yield, before draining	94.8±0.70	95.7±0.23	96.2±0.77	96.5*±0.51	95.7±0.70
Cook yield, after draining	70.5±2.1	69.6±1.3	67.9±0.63	63.8*±1.1	66.2*±1.9
Color Analysis					
L*	38.6±0.56	38.5±0.22	37.5±0.40	35.6*±0.34	31.0*±0.36
a*	5.60±0.22	4.49*±0.16	4.60*±0.40	4.90*±0.34	5.33±0.36
b*	14.4±0.80	15.0±0.32	14.8±0.87	14.7±0.34	12.7±0.36
Texture Analysis (kPa)					
Maximum stress	17.0±1.6	16.7±1.5	14.3*±0.74	8.81*±0.61	5.02*±0.46
Residual stress	6.76±0.56	4.85*±0.14	2.58*±0.19	1.18*±0.15	0.530*±0.079

Mushrooms have higher water content than ground beef (90% and 60% respectively), which was reflected in the increase in water content with increasing mushroom concentration (Table 3). This finding was supported by previous work conducted on oyster mushrooms in beef patties and white jelly mushrooms in pork patties (Wan Rosli & Solihah, 2012; Cha et al., 2014). However, the addition of oyster mushrooms in chicken patties has shown not to alter moisture content (Wan Rosli et al., 2011).

Mushrooms affected cooking yield both before and after cooking liquid was removed. As seen in Table 3, cook yield before draining was greatest for the formulation containing 75% mushroom when compared to the all-meat control suggesting that water in the mushrooms did not evaporate during cooking as fast as in the ground beef.

Cooking yield after draining was lowest for the formulation containing 75% mushroom indicating that all the water released from the mushrooms during cooking could not be entrapped in the mixture. Research has shown that mushrooms have varying effects on product cook yield. Increasing the concentration of white jelly mushrooms in pork patties and resulted in decreased cook yield (Cha et al., 2014). However, increasing the concentration of decreased cook yield while supplementation into chicken patties had no effect (Wan Rosli et al., 2011; Wan Rosli & Solihah, 2012).

Another physical characteristic influenced by mushroom concentration was color. In general, lightness (L*) of the cooked formulations decreased as mushroom concentration increased with statistical differentiation from the all-meat control starting at 75% mushroom (Table 3). Mushroom concentration from 25% to 75% had less red color (lower a* values) than the all-meat control. Finally, the only formulation with a differing yellow color (b* value) from the all-meat control was the 100% mushroom formula. The results of this test suggest that red color was statistically decreased across all mushroom concentrations, while lightness and yellow color decreased at 75% and 100% mushroom respectively. The addition of the white button mushrooms that browned during cooking may have darkened the meat and diluted the red color by lowering the level of myoglobin found in the meat. Previous work has reported inconsistent findings on mushroom's effect on color due to its dependency on meat and mushroom type. Greyish-white oyster mushrooms have shown to reduce the lightness and yellow color of chicken patties, but had no effect on red color (Wan Rosli et al., 2011). Oppositely, white jelly mushrooms incorporated into pork patties increased lightness and yellow color values, but decreased red color (Cha et al., 2014).

The results from the texture analysis in Table 3 showed that maximum stress decreased with increasing mushroom concentration with statistical differentiation starting at 50% mushroom and higher. Residual stress significantly decreased with the addition of mushrooms at all concentrations. Wan Rosli and coworkers showed decreased hardness values for chicken patties supplemented with lower concentrations (25% and 50%) of oyster mushrooms, which supported these findings (Wan Rosli et al., 2011). These differences in product texture between the past research and current findings could be due to factors such as meat type, mushroom type, cooking time, and cooking temperature.

3.3.2 Impact of Mushroom Type, Blanching, Size, and Concentration on Taco Filling Physical Characteristics

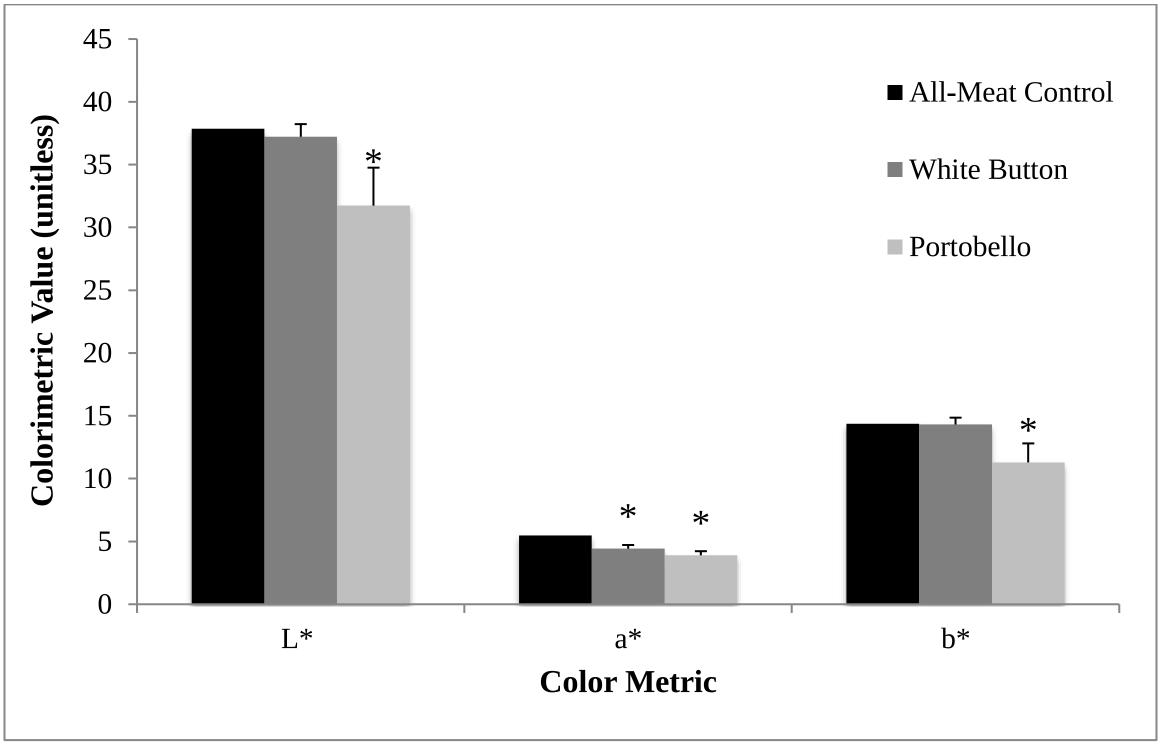
A second series of physical characterization was analyzed to identify which mushroom type, blanching, particle size, and concentration created a ground beef and mushroom formulation that was similar to the all-meat control. Lower mushroom concentrations, 15%, 30%, and 45% mushroom by weight, were used since mushroom concentration above 50% caused deviations from the all-meat control in yield after draining, color, and texture as determined in the first physical analysis. Bolded ANOVA p-values in Table 4 indicated differences among ground beef and mushroom formulations for specific mushroom variables.

Table 4. ANOVA p-values for each source of variation for each physical test metric. Note: Significance at $P \leq 0.05$ is shown with an * in bold.

Source of Variation	Moisture Content	Cook Yield, Before Draining	Cook Yield, After Draining	L*	a*	b*	Maximum Stress	Residual Stress

White Button vs. Portobello (Type)	0.9212	0.1121	0.2419	**0.0010***	**0.0277***	**0.0203***	0.1185	0.4899
Blanching vs. Non-blanching	0.8360	0.2225	0.9030	0.3727	**0.0110***	0.1099	0.7032	0.6584
Small vs. Large Particle Size	**0.0380***	0.1851	0.4460	0.4919	0.5660	0.9670	**0.0300***	0.3768
Mushroom Concentration	**0.0001***	**0.0059***	0.0839	**0.0012***	**0.0011***	**<0.0001***	**0.0222***	**0.0003***
Type*Blanching	**0.0446***	0.8692	0.9018	0.3760	0.8644	0.9559	0.4768	0.5491
Type*Size	0.3138	0.1943	0.6027	**0.0001***	0.0787	**0.0129***	0.3323	0.3551
Type*Concentration	0.6556	0.8868	0.6887	0.3850	0.9665	0.3055	0.9967	0.7619
Blanching*Size	0.2522	0.0814	0.8890	0.1711	0.3837	0.0600	0.2651	0.6306
Blanching* Concentration	0.2713	**0.0269***	0.2792	0.2240	0.7371	0.8498	0.1833	0.1758
Size*Concentration	0.4290	0.1223	0.5458	0.9817	0.3151	0.9913	**0.0431***	0.0525
Type*Blanching*Size	0.9538	0.0821	0.1521	0.0803	0.0710	0.0837	0.4281	0.5491
Type*Blanching* Concentration	0.2626	**0.0199***	**0.0409***	0.0834	0.9733	0.7661	0.8661	0.6801
Type*Size* Concentration	0.0790	0.2006	0.5292	0.9997	0.6883	0.1783	0.0722	0.3049
Blanching*Size* Concentration	0.8831	0.2502	0.2323	0.4628	0.9387	0.2040	0.4974	0.2801
Type*Blanching *Size*Concentration	0.8922	0.1314	0.7174	0.2586	0.2670	0.1579	0.4408	0.5612

Figure 1. Effect on formulation color with the inclusion of white button and portobello mushrooms to ground beef in terms of L* (lightness), a* (red color), and b* (yellow color) values. Note: Columns with an * indicate a significant difference from the all-meat control within a group of columns (Dunnett, P=0.05).



As seen in Table 4, significant differences in moisture content, yield, and texture were not found between formulations containing white button or portobello mushrooms. However, varying mushroom type in formulations affected all three color metrics. Figure 1 showed how formulations containing white button mushroom were similar to the all-meat control in terms of lightness (L*) and yellow color (b*), but differed in terms of red color (a*). Figure 1 also showed how formulations containing portobello mushroom differed from the all-meat control across all three color metrics. Therefore, white button mushrooms were selected as the mushroom type for further testing due to their more similar color to the all-meat control than portobello mushrooms.

Blanching did not affect formulation moisture content, yield, lightness (L*), yellow color (b*), and texture (Table 4). Although a statistical difference was found in red color (a*), the relative effect amongst the formulations was minor and not a practical difference for the research (data not shown). Since no substantial differences were observed between formulations containing blanched and non-blanched mushrooms across all tests, non-blanched mushrooms were selected for further testing, as they would require less processing and thus would be more economical.

No significant differences in yield, color, and residual stress were found between formulations containing small and large mushroom particles (Table 4). The ANOVA identified a statistical difference in moisture content and texture maximum stress, however further statistical analysis with the Dunnett's Test revealed that these differences were minor and did not impart a significant effect on the research from a practical standpoint (data not shown). Although no substantial differences were detected by analytical methods, empirical observation concluded that formulations containing small mushroom particles appeared more similar to the all-meat control, thus small particle size was selected for further testing.

Finally, varying mushroom concentration in formulations did not affect yield after draining, but did affect moisture content, yield before draining, color, and texture (Table 4). The mushroom concentration findings resulting from the second set of physical characterization tests were found to be consistent with the findings from the first set of physical characterization tests that solely focused on the effects of mushroom concentration (data not shown). The 30% and 45% mushroom concentrations were selected for further testing to maximize mushroom usage in the taco filling while still using concentrations that produced minimal differentiation from the all-meat control.

Another objective of this study was to determine if mushrooms could decrease sodium levels, in the form of salt, in taco filling. The water-binding properties of salt have been shown to increase water uptake when added to meat products (Hamm, 1960; Offer & Trinick, 1982) and thus could impact the properties of the taco filling. Therefore, a third set of physical tests was conducted to investigate the potential effects of salt (0.53%, 0.68%, 0.82%, and 0.97% by weight) on ground beef and mushroom formulations. The CIA taco filling recipe had a salt concentration of 0.97% (Table 1) and was deemed the control, or full salt, level while 0.82%, 0.68%, and 0.53% equaled 15%, 30%, and 45% reductions from the control respectively. Formulations contained non-blanched white button mushrooms chopped to a small particle size. These mushroom variables were kept consistent to solely investigate the effects of the varied salt levels. The results of this testing showed that the level of salt used in this experiment did not affect cook yield, moisture content, color, or texture (data not shown).

Although many formulations had differences as detected by analytical methods, these results might correspond to differences deemed important by consumers. For example, Chung and coworkers identified changes in color and texture when cuttlefish surimi gel was supplemented with up to 50% cubed king oyster mushroom, however color likability and overall acceptance did not change when the gels were sampled by a trained panel (Chung, Kim, Nam, & Kang, 2010). Frankfurters supplemented with shiitake powder up to 1.2% also displayed differences in color and texture. However, the trained panel evaluating the formulations deemed texture likability of the variants similar to the un-supplemented control and overall acceptance higher than the control at 0.8% to 1.2% shiitake powder concentration by weight (Pil-Nam et al., 2015). Finally, pork patties with up to 30% ground white jelly mushroom showed differences in color compared to the control, but no differences in color likability were identified in the hedonic study (Cha et al., 2014).

3.3.3 Hedonic Sensory Study

Due to potentially conflicting conclusions between analytical and sensory testing, mushroom concentrations and salt levels were further investigated by hedonic sensory analysis to identify formulations that were most accepted by consumers. This sensory study utilized 30% and 45% mushrooms since these showed similar characteristics to the all-meat control. A range of salt reductions (0.97%, 0.82%, 0.68%, and 0.53% salt by weight; 0%, 15%, 30%, and 45% less salt respectively) was tested in formulations containing 30% mushroom to identify a threshold of liking for salt reductions in formulations containing mushroom. The sensory study had the capacity to include two additional formulations containing 45% mushroom to investigate likability at this mushroom level with full and 30% less salt compared to the all-meat control.

Figure 2. Spider web plot showing the mean liking intensities of the sensory attributes for the fielded taco filling hedonic study identifying most liked mushroom concentration and salt level (Duncan's New Multiple Range Test, * = P=0.05, ** = P=0.01).

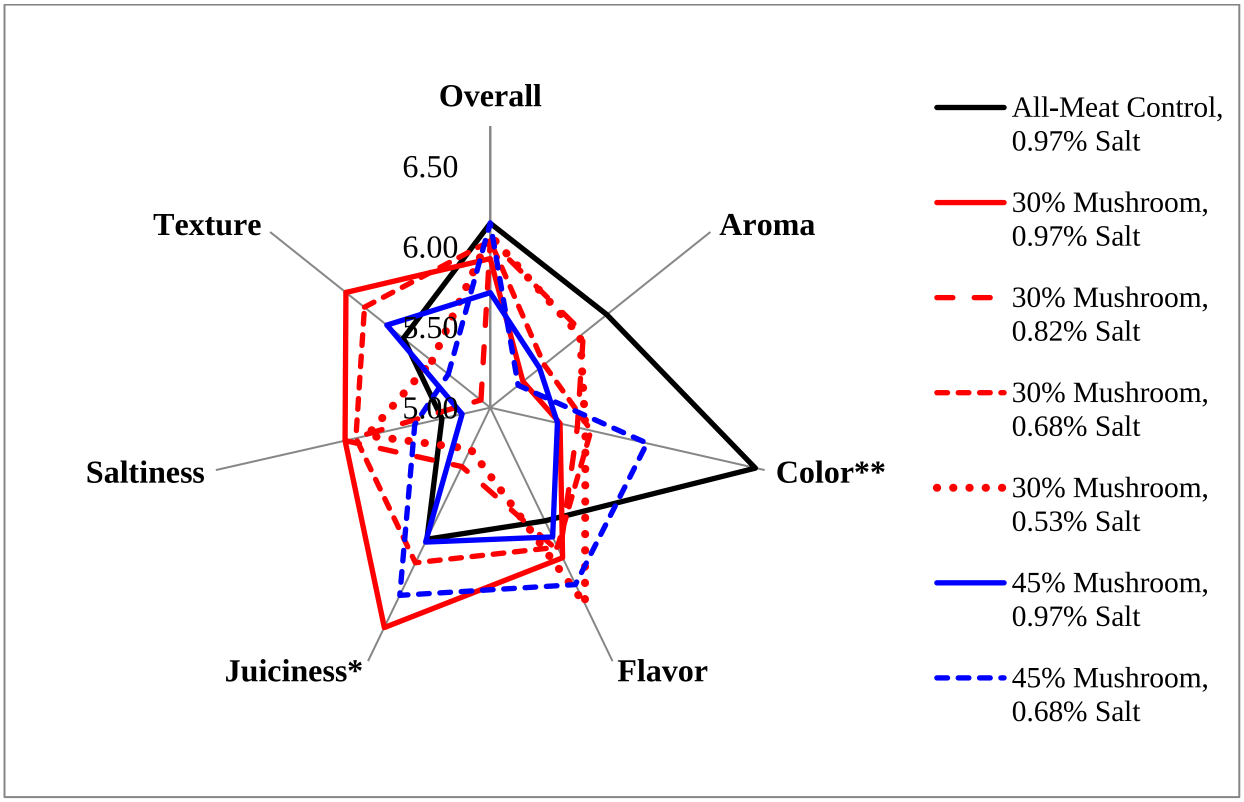


Table 5. Average liking values of the sensory attributes for the fielded taco filling hedonic study identifying most liked mushroom concentration and salt level. Values within a column with at least one similar letter label are statistically similar (Duncan's New Multiple Range Test, * = P=0.05, ** = P=0.01).

Formulation	Overall	Aroma	Color**	Flavor	Juiciness*	Saltiness	Texture
All-Meat Control, 0.97% Salt	6.15a	5.93a	6.69a	5.78a	5.91ab	5.31a	5.69a
30% Mushroom, 0.97% Salt	5.93a	5.26a	5.44b	6.04a	6.52a	5.93a	6.15a
30% Mushroom, 0.82% Salt	6.04a	5.74a	5.56b	6.00a	5.41ab	5.93a	5.07a
30% Mushroom, 0.68% Salt	6.04a	5.43a	5.64b	5.96a	6.07ab	5.86a	6.00a
30% Mushroom, 0.53% Salt	6.07a	5.17a	5.61b	6.36a	5.29b	5.79a	5.46a
45% Mushroom, 0.97% Salt	5.71a	5.39a	5.43b	5.89a	5.93ab	5.18a	5.82a
45% Mushroom, 0.68% Salt	6.15a	5.22a	6.00a	6.22a	6.30ab	5.48a	5.33a

The hedonic sensory test used 55 untrained panelists and formulations with 80/20 blend ground beef, non-blanched white button mushrooms chopped to a small particle size, taco seasoning, and salt to investigate the effects of mushroom concentration and salt level on consumer liking. Results from Figure 2 and Table 5 showed that the overall liking of variant formulations with mushroom was similar to the all-meat control. However, color and juiciness scores varied among the formulations with statistical difference demonstrated with an * or ** (Figure 2). Test subjects scored color liking lower for all of the formulations containing mushrooms compared to the all-meat control. This could correspond to the differences in red color (a*) at these mushroom concentrations (Table 2). Differences in juiciness scores were found among variant formulations but there was no consistent trend with liking and mushroom concentration or salt level. This result suggests that mushroom concentration and salt level did not affect juiciness liking of the variant formulations against the all-meat full salt control. The results from this test showed that consumers may equally like the all-meat full salt control and a taco filling containing 30% to 45% mushroom and up to 45% less salt, but might not like the color as much.

Some of these findings were supported by previous hedonic sensory work conducted on mushrooms incorporated into taco blend products (Guinard et al., 2016). Guinard and coworkers partially substituted taco blend formulations with 50% or 80% mushroom with full or 25% less salt. The results from this study confirmed the acceptability of mushroom substitution up to 80% against the all-meat control and showed statistically similar overall liking to the all-meat control at higher levels of mushroom substitution with a trained panel. The results also found that full salt formulations were significantly more liked overall than their reduced salt counterparts, which differs from the current findings. Mushrooms have the potential to maintain quality attributes and consumer acceptability of reduced salt products at mushroom substitution levels of 45% or less as shown in the current findings, however this may not be successful at mushroom substitution levels of 50% or higher as shown in the work from Guinard and coworkers.

3.3.4 Paired Preference Sensory Studies

Two different paired preference studies were conducted. The first study evaluated the consumer acceptance of taco filling with the addition of mushrooms. Panelists consisted of 46.5% females and 53.5% males ranging in age from 15 to 25 years. The control formulation consisted of 100% ground beef by weight with no mushroom and full salt while the variant formulation consisted of 55% ground beef with 45% mushroom and full salt. The 45% mushroom concentration was selected for the test based on its similar physical characteristics compared to the all-meat control. Previous results from the hedonic study (Figure 2 and Table 5) suggested that taco fillings with 45% mushroom could achieve similar overall liking to the all-meat control. The results of this paired preference study indicated that mushroom could be incorporated into taco filling while still deemed acceptable by consumers. Statistical analysis showed that there was no significant difference in the number of participants who preferred each formulation therefore resulting in parity preference (N = 159: 83 preferred the all-meat control; 76 preferred the formulation containing mushroom).

The second sensory study evaluated the consumer acceptance of a reduced salt taco filling. Panelists consisted of 49.4% females and 50.6% males ranging in ages from

15 to 29 years. The control formulation consisted of 55% ground beef with 45% mushroom and full salt while the variant formulation consisted of 55% ground beef with 45% mushroom and 45% less salt compared to the control. The variant formulation achieved both a "reduced fat" and "reduced sodium" claim when compared to the all-meat control (Code of Federal Regulations, 2011). The results of this paired preference study indicated that less salt could be incorporated into a taco filling containing mushrooms while still deemed acceptable by consumers Statistical analysis showed preference of the reduced sodium formulation with 45% less salt over the control containing full salt (N = 158: 55 preferred the control; 100 preferred the reduced salt formulation).

3.4 Conclusion

Physical analysis indicated that both white button and portobello mushrooms could be substituted for ground beef without dramatically changing its properties up to a level of 45% mushroom. However, portobello mushrooms altered formulation color suggesting that they might not be suitable for substitution. Neither blanching the mushrooms nor changing their particle size improved the physical properties of the taco filling. Hedonic sensory analysis confirmed the physical findings with the exception of color where red color decreased in the presence of the mushroom and consumer acceptability of color also decreased. Sensory data from untrained consumers found that taco filling prepared with 45% mushroom and 45% less salt was preferred over the full salt formulation also containing 45% mushroom. Preference with lower salt levels could be due to the umami or other flavors of the mushrooms, which would improve the taco flavor. The acceptance of this 80/20 ground beef blended with 45% mushroom and reduced salt taco filling by consumers suggests that mushrooms have the potential to be successfully incorporated into American, meat products to help lower sodium consumption, while providing a healthier product. In fact, the final formulation developed in this research would quality for a “reduced fat” and “reduced sodium” claim while simultaneously increasing vegetable consumption.

CHAPTER 4

UTILIZING MUSHROOMS TO REDUCE OVERALL FAT IN TACO FILLING USING PHYSICAL AND SENSORY EVALUATION

4.1 Introduction

In general, previous research on using mushrooms as a meat extender suggested that mushrooms could be advantageous in improving nutritional quality of beef-based products due to their lower levels of calories, sodium, fat, and cholesterol compared to ground beef. However, limited research has looked at mushroom's effect on meat product fact content compared to their all-meat counterparts. Additional research is needed to further investigate mushroom's fat reducing capacity while maintaining quality consumers accept. Therefore, the objective of this research was to investigate the effect of reduced fat taco fillings with various mushroom concentrations and ground beef fat contents on both physical properties and consumer acceptance. Again, in order to optimize mushrooms as an ingredient that can make the most sensory acceptable and healthiest meat products possible.

4.2 Materials and Methods

4.2.1 Mushroom and Beef Preparation

All suppliers, recipes, and methods for formulation preparation were kept consistent with Section 3.2.1. Arnold's Meats (Chicopee, MA, U.S.A.) supplied not only the same 80/20 lean fat blend ground beef but also provided 85/15 and 90/10 ground beef blends.

4.2.2 Preparation for Physical Testing

All methods for formulation preparation and cooking for physical testing were kept consistent with Section 3.2.2

4.2.3 Physical Characterization Tests

All methods for the cook yield test, moisture content test, color analysis, and texture analysis were kept consistent with Sections 3.2.3 through 3.2.6. Cooking liquid was not drained for formulations in this experiment.

4.2.4 Fat Analysis

Fat content analysis was executed by extraction with diethyl ether using a Soxhlet apparatus with Allihn condenser (Thermo Fischer Scientific, Waltham, MA, U.S.A.) based on AOAC Method 960.39. Before extraction, a 30 g sample of formulation was placed into a plastic petri dish (Thermo Fischer Scientific, Waltham, MA, U.S.A.) and put into a -40°C freezer (Environmental Equipment Company, Cincinnati, OH, U.S.A.) for at least 24 hours. Thoroughly frozen samples were then dried in a freeze dryer (Virtis Consol 12LL, The Virtis Company Inc., Gardiner, NY, U.S.A.) for 24 to 48 hours and then ground to a fine powder using a grinder (Krups F203 Grinder, Krups, Groupe SEB, Ecully, France). Powder samples were then used for the analysis. Results were reported in percent by weight.

4.2.5 Culinary Application and Execution for Sensory Testing

All methods for formulation preparation, hedonic sensory test execution, and paired preference sensory test execution were kept consistent with Sections 3.2.8 through 3.2.10.

4.2.6 Statistical Analysis

All methods for statistical analysis using the ANOVA, Dunnett's Test, Duncan's New Multiple Range Test, and Z-score calculation were kept consistent with Section 3.2.11.

4.3 Results and Discussion

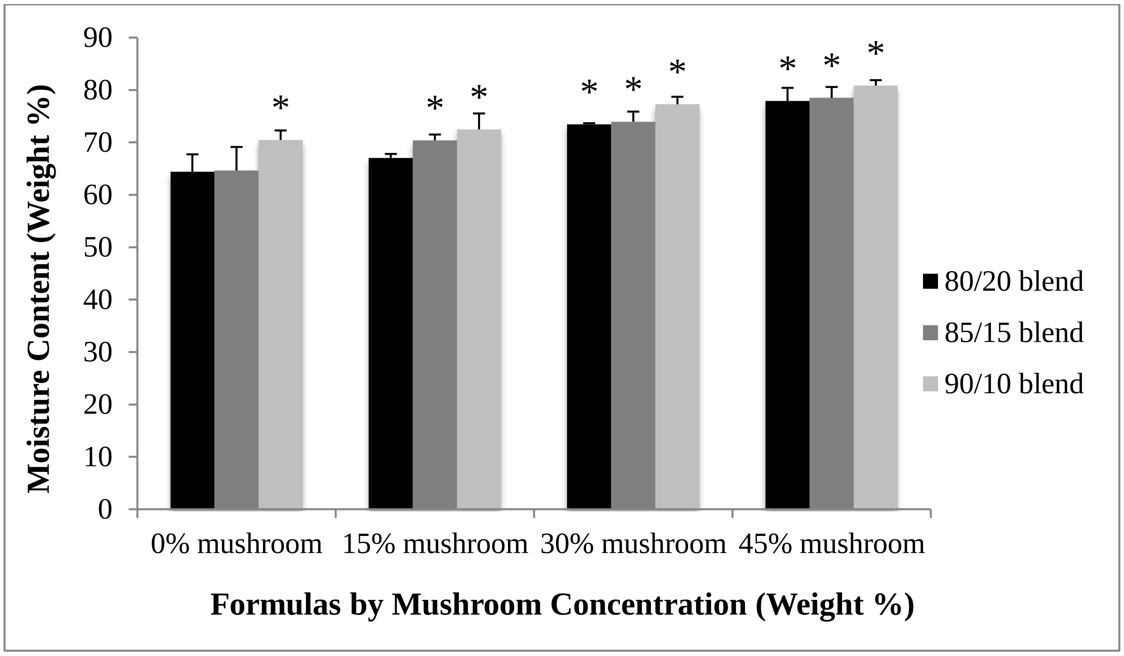
4.3.1 Impact of Ground Beef Fat Content and Mushroom Concentration on Taco Filling Physical Characteristics

The fat reduction capacity of mushrooms was first evaluated with a set of physical characterization tests, which focused on identifying the effect of varying overall fat content by using different protein to fat blend ratios on the physical attributes of taco filling in addition to varying mushroom concentration. All formulations contained non-blanched white button mushrooms chopped to a small particle size at concentrations of 0%, 15%, 30%, and 45% by weight. Overall fat content in the formulations was modified by using 80/20, 85/15, and 90/10 protein to fat blend ratios or "fat levels". The all-meat control contained the 80/20 blend. A fat analysis was added to this set of tests to determine if a certain combination of mushroom concentration and fat level could reduce the overall fat content of a formulation by at least 25%, compared to the all-meat (80/20) control, to achieve a "reduced fat" claim.

Table 6. ANOVA p-values for each source of variation for each physical test metric. Note: Significance at P ≤ 0.05 is shown with an * in bold.

Source of Variation	Moisture Content	Cook Yield	L*	a*	b*	Maximum Stress	Residual Stress	Overall Fat Content
Mushroom Concentration	**<0.0001***	0.0574	0.4963	**0.0004***	0.7484	**<0.0001***	**<0.0001***	**0.0004***
Fat Level	**0.0150***	0.8477	0.0713	0.7600	0.3472	0.3362	0.7853	**0.0180***
Concentration *Fat Level	0.7437	0.5962	0.0557	**0.0215***	0.1006	0.5270	0.5779	0.0714

Figure 3. Effect of mushroom concentration and fat level on moisture content. Note: The far left column is set as the control (80/20 blend, 0% mushroom). Columns with an * indicate a significant difference from the control (Dunnett, P=0.05).



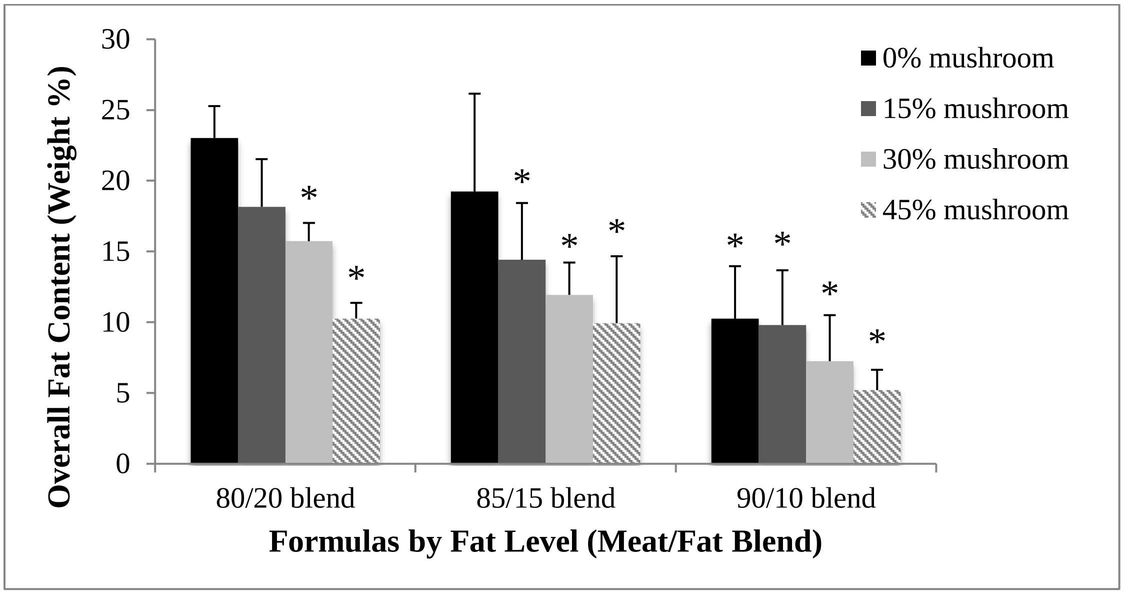
Both mushroom concentration and fat level were shown to have a statistically significant effect on moisture content (Table 6). The effect of mushroom concentration on moisture content was consistent with previous findings: moisture content increased with mushroom concentration. Fat level also affected moisture content where generally moisture content increased as fat level decreased. Also, Figure 3 showed that as mushroom concentration increased, the variation in moisture contents decreased amongst the fat levels. This may be due to the high level of moisture contributed by the mushroom at the higher concentration (30% and 45%), which might have neutralized any differences coming from the varying fat levels.

Statistical analysis showed that varying mushroom concentration and fat level did not significantly alter the cook yield of the un-drained formulations (Table 6). Preliminary testing showed that draining formulations prior to physical analysis testing neutralized any fat reducing effects from the mushrooms and thus this step was removed (data not shown).

Fat level did not have a statistically significant effect on any of the three formulation color metrics (Table 6). However, mushroom concentration statistically affected red color in a way that was consistent with previous test results (data not shown). Mushroom concentration did not significantly affect lightness or yellow color, which again was consistent with previous test results (data not shown).

Texture analysis results showed that fat levels did not affect either texture metric, however a statistically significant difference was identified among the various mushroom concentration formulations for both metrics (Table 6). However, further statistical analysis with the Dunnett's Test revealed that the difference or differences identified in the ANOVA were not between the control formulation (80/20 blend, 0% mushroom) and the variant formulations and thus did not impart a significant effect on the research from a practical standpoint (data not shown).

Figure 4. Effect of mushroom concentration and fat level on overall fat content. Note: The far left column is set as the control (80/20 blend, 0% mushroom). Columns with an * indicate a significant difference from the control (Dunnett, P=0.05).



Altering both mushroom concentration and fat level statistically affected overall fat content (Table 6). At the 80/20 fat level, overall fat content was significantly lower than the control formulation at 30% mushroom concentration and higher (Figure 4). This finding suggests that mushroom substitution is capable enough to be used as a strategy to significantly reduce overall fat content in taco filling. The 85/15 and 90/10 fat levels saw statistically lower overall fat contents at 15% mushroom concentration and higher. In general, overall fat content decreased as fat level decreased. It can be noted that some overall fat contents were higher than the fat levels found in the meat blend. This can happen due to the natural deviation of fat content in ground beef from the level specified on the label. The variability found in these tests, run in triplicate, was within the allowable regulated range (no greater than 20% in excess of the stated value) according to 9 CFR 317.309(h).

Table 7. Overall fat content, grams of fat per reference amount customarily consumed (RACC), and percent of fat reduction compared to the all-meat 80/20 blend control for variant formulations with different meat/fat blends and mushroom content. Note: All formulations with an * in bold qualify for a "reduced fat" claim.

Meat/Fat Blend	Mushroom Concentration (% Weight)	Overall Fat Content (% Weight)	Grams of Fat Per RACC (g)	% Less Fat than Control (%)
80/20	0	23.03	12.66	-
80/20	15	18.16	9.99	21.15
80/20	30	15.73	8.65	**31.69***
80/20	45	10.26	5.64	**55.44***
85/15	0	19.23	10.57	16.48
85/15	15	14.40	7.92	**37.43***
85/15	30	11.94	6.56	**48.15***
85/15	45	9.93	5.46	**56.85***
90/10	0	10.25	5.63	**55.47***
90/10	15	9.80	5.39	**57.43***
90/10	30	7.25	3.99	**68.51***
90/10	45	5.20	2.86	**77.41***

The significant differences in overall fat content identified in the statistical analysis also translated into significant fat reduction percentages. The U.S. Food and Drug Administration (FDA) states that a product must contain "at least 25% less fat per reference amount customarily consumed (RACC) than an appropriate reference food" to achieve a "reduced fat" claim (U.S. Food and Drug Administration, 2013). The RACC for taco meat is 55 grams for taco meat according to CFR 317.312. Table 7 showed that 9 of the 11 variant formulations achieved a large enough fat reduction to qualify for a "reduced fat" claim. This finding suggests that the combination of mushroom substitution and ground beef fat level variation is also capable enough to be used as a strategy to significantly reduce overall fat content in taco filling.

4.3.2 Hedonic Sensory Study

Due to potentially conflicting conclusions between analytical and sensory testing, ground beef fat levels were further investigated by hedonic sensory analysis. The effect of salt reduction was also further investigated to identify any interactions with the varied fat levels noticed by consumers. The objective of this study was to identify fat and salt levels that were most accepted by consumers. The control formulation consisted of 100% 80/20 ground beef by weight with no mushroom and full salt (0.97% by weight, Table 1). This sensory study used a 45% mushroom concentration for all variant formulations since previous testing deemed this concentration acceptable by consumers when compared to the all-meat control. Mushroom was used in all variant formulations to also identify any interactions with the varied fat and salt levels noticed by consumers. The 6 variant formulations consisted of the 55% 80/20, 85/15, or 90/10 meat blend by weight with full or 45% less salt (0.97% and 0.68% by weight respectively).

Figure 5. Spider web plot showing the mean liking intensities of the sensory attributes for the fielded taco filling hedonic study identifying most liked fat and salt level (Duncan's New Multiple Range Test, * = P=0.05, ** = P=0.01).

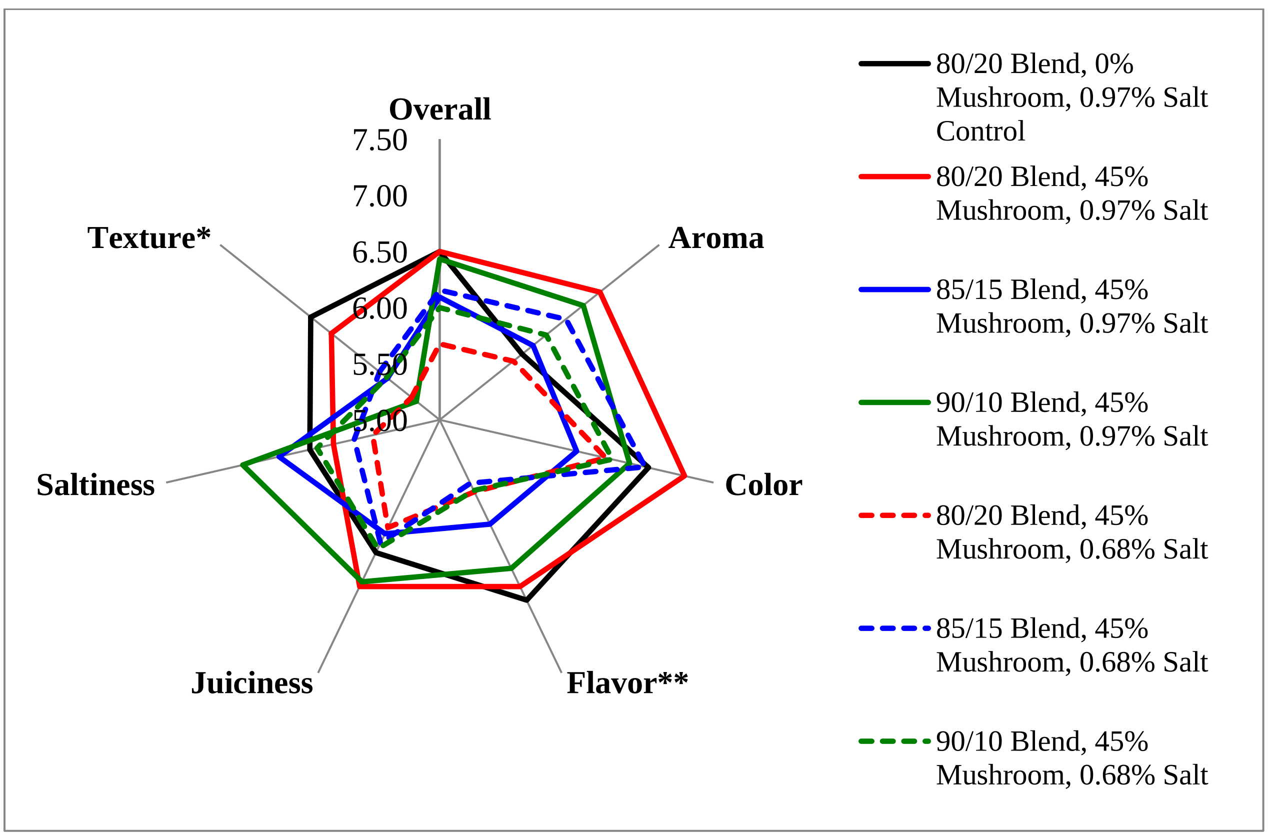


Table 8. Average liking values of the sensory attributes for the fielded taco filling hedonic study identifying most liked fat and salt level. Values within a column with at least one similar letter label are statistically similar (Duncan's New Multiple Range Test * = P=0.05, ** = P=0.01).

Formulation	Overall	Aroma	Color	Flavor**	Juiciness	Saltiness	Texture*
80/20 blend, 0% Mushroom, 0.97% Salt Control	6.50a	5.94a	6.91a	6.78a	6.31a	6.19a	6.47a
80/20 blend, 45% Mushroom, 0.97% Salt	6.50a	6.82a	7.24a	6.65a	6.65a	5.97a	6.24ab
85/15 blend, 45% Mushroom, 0.97% Salt	6.09a	6.06a	6.25a	6.03ab	6.13a	6.47a	5.59ab
90/10 blend, 45% Mushroom, 0.97% Salt	6.43a	6.63a	6.73a	6.47ab	6.60a	6.80a	5.27b
80/20 blend, 45% Mushroom, 0.68% Salt	5.68a	5.84a	6.52a	5.71b	6.06a	5.61a	5.32b
85/15 blend, 45% Mushroom, 0.68% Salt	6.16a	6.44a	6.88a	5.63b	6.22a	5.78a	5.69ab
90/10 blend, 45% Mushroom, 0.68% Salt	6.00a	6.21a	6.58a	5.70b	6.27a	6.12a	5.61ab

The hedonic sensory test used 64 untrained panelists to investigate the effects of mushroom concentration, fat level, and salt level on consumer liking. Results from Figure 5 and Table 8 showed that the overall liking of variant formulations regardless of mushroom concentration, fat level, or salt level was similar to the all-meat full salt control. Variant formulation aroma, color, juiciness, and saltiness liking was also statistically similar to the all-meat full salt control. However, flavor and texture scores varied among the formulations with statistical difference demonstrated with an * or ** (Figure 5). Test subjects scored flavor liking lower for all of the reduced salt formulations, while all of the full salt formulations scored similarly to the all-meat full salt control regardless of the 45% mushroom concentration or varied fat level. Further statistical analysis with the Duncan's New Multiple Range Test showed that the significant difference in texture liking identified by the ANOVA was between the all-meat full salt control and 2 of the 6 variant formulations: 90/10 blend with 45% mushroom and full salt and 80/20 blend with 45% mushroom and reduced salt. This finding did not provide a consistent trend with texture liking and mushroom concentration, fat level, or salt level. This result suggests that any variation in mushroom concentration, fat level, or salt level did not affect texture liking of the variant formulations against the all-meat full salt control. The results from this test showed that consumers may equally like the all-meat (80/20 blend) full salt control and a taco filling containing 45% mushroom and up to 45% less salt consisting of any meat blend as lean as 90/10.

4.3.3 Paired Preference Sensory Study

One paired preference study was conducted to evaluate the consumer acceptance of a reduced fat taco filling. The combination of mushroom substitution and leaner meat blend was used to create the reduced fat formulation. Panelists consisted of 49.69% females and 50.31% males ranging in ages from 15 to 29 years. The control formulation consisted of 100%, by weight, 80/20 ground beef with no mushroom while the variant formulation consisted of 55%, by weight, 90/10 ground beef with 45% mushroom. Salt level was kept consistent for this study to solely investigate the effects of a reduced fat taco filling on consumer acceptance. Prior physical analysis qualified the variant formulation for a "reduced fat" claim. The results of this study indicated that taco fillings with leaner meat and the inclusion of mushrooms could not be preferred over its all-meat counterpart. These results also indicate that the acceptance of mushroom in meat application can be influenced by meat blend. Although the hedonic data showed that leaner formulations might be equally liked to the control, they did not achieve parity when fielded during the paired preference test. Statistical analysis showed preference of the control formulation over the variant formulation (N = 159: 101 preferred the control; 58 preferred the variant).

4.4 Conclusion

This research investigated the effect of reduced fat taco fillings incorporated with various mushroom concentrations and ground beef fat contents on both physical characteristics and consumer acceptance. Variation in mushroom concentration resulted in findings consistent with previous testing. Increased mushroom concentration generally increased moisture content, decreased red color, and decreased overall fat content while leaving formulation cook yield, lightness, yellow color, and texture unaffected. Physical analysis also showed that decreasing fat level by using leaner meat blends resulted in increased moisture content and decreased overall fat content while formulation cook yield, color, and texture remained unaffected. The results from this set of physical characterization tests showed that the combined effect of mushroom substitution and ground beef fat level variation can significantly reduce the overall fat content of a taco filling while keeping maintaining other quality attributes. Hedonic sensory analysis confirmed the physical findings and showed that variation in mushroom concentration, fat level, and salt level did not affect consumer liking with the exception of salt reduction affecting flavor liking. Although the results from the hedonic study indicated that a taco filling containing mushrooms and leaner meat could be equally liked to a full fat all-meat counterpart, sensory data from untrained consumers found that this was not the case. The findings from this research suggest that mushroom inclusion and leaner meat blends can result in similar characteristics to all-meat products, however the consumer acceptance of mushroom in these products can be influenced by meat blend and must be considered when used as a fat reduction strategy in meat applications.

CHAPTER 5

INVESTIGATING THE USE OF MUSHROOMS IN BEEF PATTY APPLICATION TO REDUCE SODIUM

5.1 Introduction

Previous research has shown how incorporation of mushrooms into burger patties improved physical quality while deemed acceptable to untrained panelists during sensory evaluation. Other work has successfully shown how umami characteristics in mushrooms can be used to mitigate flavor loss in sodium reduced products, however with limited application to beef taco filling. Umami characteristics have the potential to make mushrooms a more advantageous meat extender over other ingredients such as soy which has shown to decrease overall and meat flavors while imparting unwanted bean flavor. Additional research is needed to further investigate mushroom's sodium reducing capacity compared to other extenders in a wider variety of meat-based products. Therefore, the objective of this research was to investigate the effect of mushroom umami characteristics as a sodium reduction strategy compared to textured soy in beef patties using sensory analysis and physical characterization analysis as formulation guidance.

5.2 Materials and Methods

5.2.1 Suppliers and Ingredient Preparation

Arnold's Meats (Chicopee, MA, U.S.A.) supplied the 80/20 blend ground beef as well as the 9.52 mm diced, individually quick frozen (IQF) white button mushrooms (immature *Agaricus bisporus*) used for burger patty formulation. The IQF mushrooms were placed into a food processor (Cuisinart, East Windsor, NJ, U.S.A.) for 6 one-second pulses to obtain small particulate (1 to 5 mm). This protocol yielded 95% to 99% of particulate in the desired size range. Previous experiments have shown that a particulate size of 1 to 5 mm can be successfully incorporated into meat products. Solae (St. Louis, MO, U.S.A.) supplied Response 4320 textured soy protein concentrate (TSP). The TSP was caramel colored and ranged in size from 2 mm to 6 mm which fell with in the mushroom size range. Before burger patty formulation, the TSP was hydrated at a 1:1 ratio with hot water in a stand mixer (KitchenAid, Benton Harbor, MI, U.S.A.) with a paddle attachment on low speed for 5 minutes. Finally, salt was purchased from a local supplier.

5.2.2 Preparation for Physical Testing

Initial physical characterization tests were conducted on burger patties with varying ratios of 80/20 ground beef and meat extender, either mushroom or TSP (Table 9). Appropriate weights of ground beef and meat extender were placed in a stand mixer with a dough hook attachment and mixed on low speed for 5 minutes. Once homogeneous, the formulation was divided into 56.7 g portions and shaped using a mini burger press (Norpro, Everett, WA, U.S.A.). Patties were shaped to a uniform size with a 65 mm diameter and 17 mm thickness. Patties were then placed in a 305 mm diameter aluminum frying pan (Pedrini, Lifetime Brands, Garden City, NY, U.S.A.) on an electric range (Kenmore 94173, Kenmore, Chicago, IL). Patties were cooked on one side at medium heat for 3 minutes, flipped, and cooked for an additional 3 minutes until the internal temperature reached 74˚C. Internal temperature was taken by inserting a temperature probe (Thermo Fischer Scientific, Waltham, MA, U.S.A.) into the center of the patty through the side.

Table 9. Ground beef (80/20 blend) and meat extender (mushroom or textured soy) formulations by weight for physical characterization tests.

Formulation	Ground Beef (% Weight)	Meat Extender Type	Meat Extender (% Weight)
1 (Control)	100	-	-
2	90	Mushroom	10
3	80	Mushroom	20
4	70	Mushroom	30
5	60	Mushroom	40
6	50	Mushroom	50
7	90	Textured Soy	10
8	80	Textured Soy	20
9	70	Textured Soy	30
10	60	Textured Soy	40
11	50	Textured Soy	50

5.2.3 Cook Yield Test

Cook yield was determined by measuring the weight of each patty before and after cooking using the following equation and the results were reported as percentages (Wan Rosli et al., 2011): Cook Yield (%) = (Cooked Weight/Pre-Cooked Weight) * 100.

5.2.4 Moisture Content and Retention Test

Moisture content was measured (AOAC Method 950.46 A) by placing 2 ± 0.01 grams of patty in a 57.2 mm diameter aluminum, weighing dish (Scientific Equipment of Houston, Navasota, TX) and placed in a vacuum oven (Lab-Lane Instruments, Melrose Park, IL) connected to a rotary vacuum pump (FJC, Mooresville, NC). Oven temperature was 100°C and pressure was 100 mm Hg. Drying was conducted until the weight of the samples was constant. Moisture retention was calculated using the following equation (El-Magoli, Laroia, & Hansen, 1996): Moisture Retention (%) = (Percent Yield * Percent Moisture in Cooked Patty) / 100. Results were reported as percent moisture and percent moisture retained.

5.2.5 Color Analysis

Color measurements of samples were determined using a colorimeter (ColorFlex EZ™, Hunter Lab, Reston, VA) on the L*a*b* scale. A patty was placed on a plastic petri dish (Thermo Fischer Scientific, Waltham, MA) and covered with a black, metal cup to provide a consistent, black background. The instrument was calibrated with a white Illuminant D65 10° Observer ASTM E308: X: 79.59, Y: 84.44, and Z: 87.25 standard. Results were reported without units.

5.2.6 Texture Analysis

Texture analysis was executed using an imperfect squeezing flow viscosimetry method as a test to evaluate the rigidity of each patty formulation (Suwonsichon & Peleg, 1999). Each patty was compressed with a circular metal probe (50 mm diameter) at a speed of 5 mm/second. Patties were compressed to 50% of their initial height for 120 seconds. Two metrics were recorded for evaluation: maximum stress and post-compression, or residual stress. Results were reported in kilopascals (kPa).

5.2.7 Sodium Analysis

Sodium content analysis was executed using an ion selective electrode based on AOAC Method 976.25. Results were reported in milligrams of sodium per gram of sample.

5.2.8 Fat Analysis and Retention Test

Fat content analysis was executed by extraction with diethyl ether using a Soxhlet apparatus with Allihn condenser (Thermo Fischer Scientific, Waltham, MA) based on AOAC Method 960.39. Before extraction, one raw patty and one cooked patty of each formulation was placed into separate plastic petri dishes and put into a -40°C freezer

(Environmental Equipment Company, Cincinnati, OH) for at least 24 hours. Thoroughly frozen samples were then dried in a freeze dryer (Virtis Consol 12LL, The Virtis Company Inc., Gardiner, NY) for 24 to 48 hours and then ground to a fine powder using a grinder (Krups F203 Grinder, Krups, Groupe SEB, Ecully, France). Powder samples were then used for the analysis. Fat retention was calculated using the following equation (El-Magoli, Laroia, & Hansen, 1996): ((Cooked Patty Weight * Percent Fat in Cooked Patty) / (Raw Patty Weight * Percent Fat in Raw Patty)) * 100. Results were reported as percent fat and percent fat retained.

5.2.9 Culinary Application for Hedonic Sensory Test

Two hedonic sensory tests were conducted during this research, each fielding different burger patty formulations (Table 10). Appropriate weights of ground beef and meat extender were placed in a stand mixer with a dough hook attachment and mixed on low speed for 5 minutes. Once homogeneous, the formulation was divided into 114 g portions and shaped by hand to a uniform shape (approximately 120 mm diameter and 15 mm thickness). Patties were then stored in between sheets of wax paper in plastic bags and stored at -18°C overnight until further use.

Table 10. Ground beef (80/20 blend) and meat extender (mushroom or textured soy) formulations by weight for each hedonic sensory study.

Formulation	Ground Beef (% Weight)	Meat Extender Type	Meat Extender (% Weight)	Salt (% Weight)
Meat Extender Concentration Optimization (Hedonic Sensory Test #1)				
1 (Control)	98.5	-	-	1.5
2	88.5	Mushroom	10	1.5
3	78.5	Mushroom	20	1.5
4	68.5	Mushroom	30	1.5
5	88.5	Textured Soy	10	1.5
6	78.5	Textured Soy	20	1.5
7	68.5	Textured Soy	30	1.5
Reduced Sodium Patties with Meat Extenders (Hedonic Sensory Test #2)				
1 (Control)	98.5	-	-	1.5
2	98.9	-	-	1.1
3	78.9	Mushroom	20	1.1
4	79.9	Textured Soy	20	1.1

Frozen patties were then placed in a 305 mm diameter aluminum frying pan (Pedrini, Lifetime Brands, Garden City, NY, U.S.A.) on an electric range (Kenmore 94173, Kenmore, Chicago, IL). Patties were cooked on one side at medium heat for 7 minutes, flipped, and cooked for an additional 7 minutes until the internal temperature reached 74˚C. Internal temperature was taken by inserting a temperature probe (Thermo Fischer Scientific, Waltham, MA, U.S.A.) into the center of the patty through the side. Cooked patties were then quartered and placed onto a grate in a slow cooker (Bella 13972, Bella Housewares, Cape Town, Z.A.) filled with 20 mm of water to keep the patties warm and moist.

5.2.10 Hedonic Sensory Test

Two hedonic preference tests were fielded at the UMass Food Science Chenoweth Laboratory following a sequential, monadic test method. Approval from the University of Massachusetts Institutional Review Board (IRB) for the Protection of

Human Subjects was obtained prior to fielding these experiments (Protocol ID 2014-2180). Test subjects were seated at isolation stations to provide a consistent test environment and reduce bias from the presence of other participants. Untrained students from the campus were recruited for the test (N=55 and N=56 respectively). The first test was set up in a block design, designed with Sensory Information Management System (SIMS) 2000 software Version 6.0 (Sensory Computer Systems LLC, Berkeley Heights, NJ, U.S.A.), with each of the test subjects randomly evaluating the 4 of the 7 tested formulations to reduce palate fatigue. The second test had each of the test subjects randomly evaluate all 4 of the tested formulations. Each test subject was given a quarter of a patty sample of the control and 3 variant formulations on 152 mm white paper plates at 66˚C to 71˚C with water. Next, test subjects used a ballot to evaluate each of the samples on a 9-point hedonic scale (1=extremely dislike, 5=neutral, and 9=extremely like) (Peryam & Pilgrim, 1957). The attributes evaluated during this test were selected based on their effect on consumer perception and preference: overall liking, aroma, color, flavor, juiciness, saltiness, and texture.

5.2.11 Statistical Analysis

Three replications of two measures were conducted on each patty formulation for each of the physical analyses. The order of analysis for each variant formulation was randomized to reduce order bias. The data from the physical analyses was evaluated using analysis of variance (ANOVA) and Dunnett's Test with SAS 9.4 Windows version 6.1.7601 (SAS Institute Inc., Cary, NC, U.S.A.). The ANOVA was selected to identify the presence of a difference amongst the variant formulations and the all-meat control for each physical test, however due to the limitations of the ANOVA it could not determine if or how many variant formulations significantly differed from the all-meat control. When significant differences were found using the ANOVA, the Dunnett's Test was conducted to directly compare each variant formulation to the all-meat control and identify specific, significant differences. The ANOVA main effect for the physical characterization tests focusing on meat extender type and concentration were "meat extender type", "meat extender concentration", and "replication". The all-meat control (0% meat extender) was included in this analysis. Each variant formulation and the all-meat control were analyzed as "treatments" for the Dunnett's Test.

Data from the hedonic sensory study was also evaluated using an ANOVA to identify a difference in liking scores amongst the variant formulations and the all-meat control. Further data analysis with Duncan's New Multiple Range Test was conducted to compare the liking scores of the variant formulations not only to the all-meat control but also to each other. This test was selected to detect differences in liking from the all-meat control as well as identifying any thresholds in liking across a range of meat extender type and concentration.

5.3 Results and Discussion

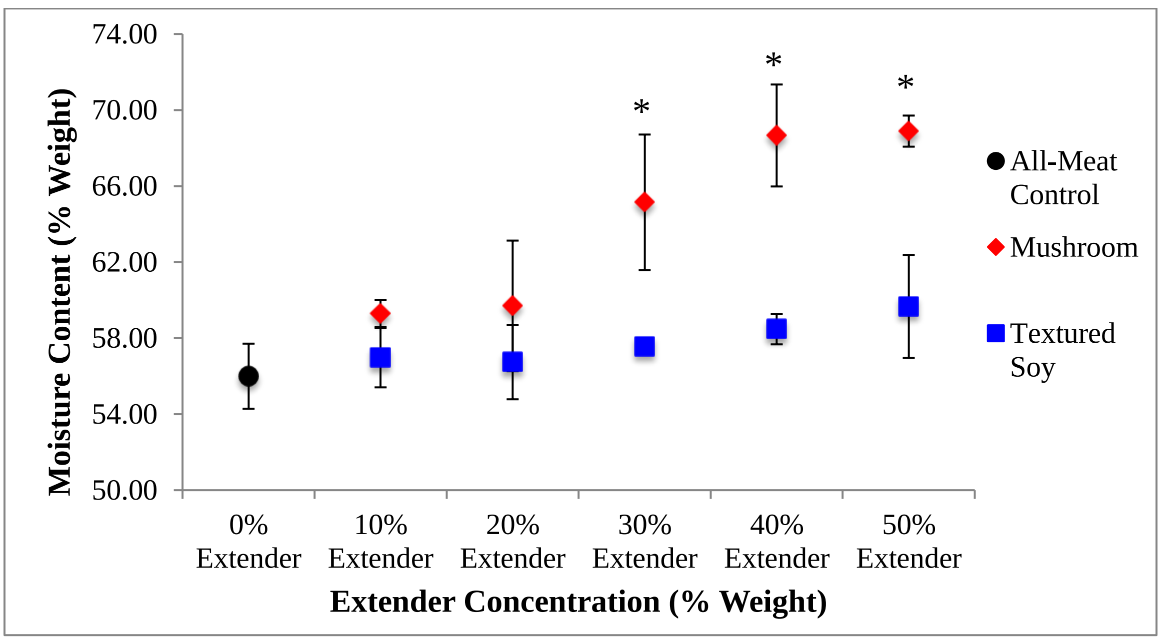
5.3.1 Impact of Meat Extender Type and Concentration on Burger Patty Physical Characteristics

One set of physical characterization tests was conducted to identify the effects of meat extender type and concentration on burger patties and which created a meat extended beef patty formulation that was similar to the all-meat control. IQF white button mushrooms and textured soy protein (TSP) were separately supplemented into burger patties at 0% 10%, 20%, 30%, 40%, and 50% by weight (Table 9). Bolded ANOVA p-values in Table 11 indicated differences among ground beef and meat extender formulations for specific meat extender variables, either type or concentration.

Table 11. ANOVA p-values for each source of variation for each physical test metric. Note: Significance at $P \leq 0.05$ is shown with an * in bold.

Source of Variation	Moisture Content	Moisture Retention	Cook Yield	L*	a*	b*	Maximum Stress	Residual Stress	Sodium Content	Fat Content	Fat Retention
Meat Extender Type	**0.0004***	**0.0060***	**0.0009***	0.1677	0.2362	**0.0046***	**0.0001***	**0.0003***	0.0939	0.0512	0.1771
Meat Extender Concentration	**<0.0001***	0.0631	0.3696	0.2504	0.0712	**0.0038***	**0.0070***	**0.0039***	**0.0012***	**0.0012***	0.0971
Type* Concentration	0.8330	**0.0134***	**0.0007***	0.5610	**0.0047***	-	0.7330	-	-	0.0501	0.4616

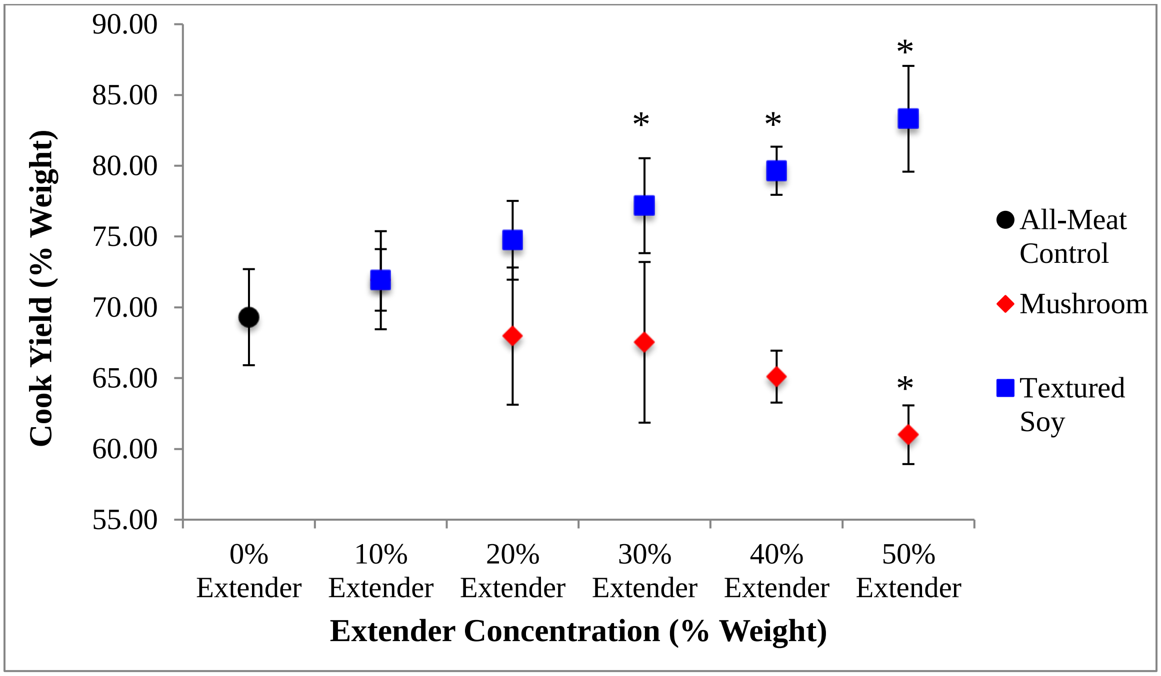
Figure 6. Effect of meat extender type (mushroom or textured soy) and meat extender concentration on moisture content. Note: The black circle is set at the all-meat control (0% extender). Data points with an * indicate a significant difference from the control (Dunnett, P=0.05).



Both meat extender type and concentration were shown to have a statistically significant effect on moisture content (Table 11). Analysis with the Dunnett's Test showed that increasing mushroom concentration increased moisture content with statistically significant increases from the all-meat control starting at 30% and higher, while increasing TSP concentration kept moisture content relatively constant with no statistical deviation from the all-meat control (Figure 6). This finding on mushroom concentration and moisture content is consistent with previous experiments and can be attributed to the higher moisture content found in mushrooms than ground beef (90% and 60% by weight respectively).

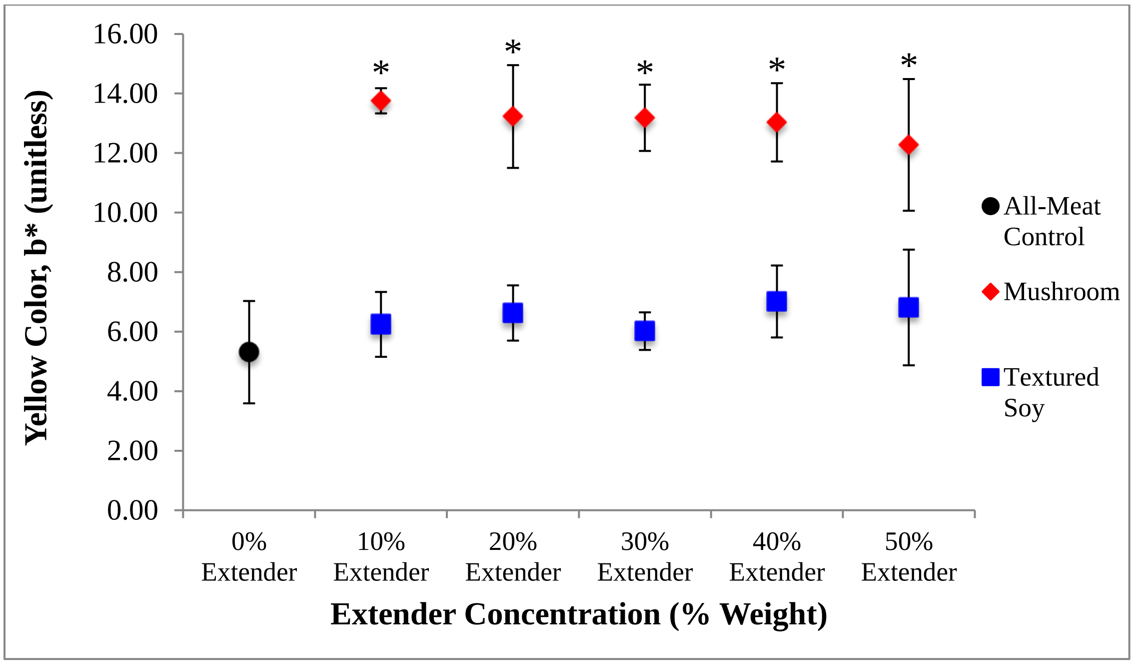
A statistical difference in moisture retention was identified among the different formulations with varying meat extender type while meat extender concentration did not impart and effect (Table 11). The Dunnett's Test revealed that only 2 of the 10 variant formulas had moisture retentions significantly different than the all-meat control. Patties with 50% mushroom had statistically lower water retention, while 50% TSP patties had statistically higher water retention than the all-meat control. This finding suggests that mushrooms or textured soy in burger patties retains water at a similar capacity to ground beef at supplementation concentrations up to 50%. After 50% supplementation, mushroom patties begin to lose more water and TSP patties retain more water than their all-meat counterpart.

Figure 7. Effect of meat extender type (mushroom or textured soy) and meat extender concentration on cook yield. Note: The black circle is set at the all-meat control (0% extender). Data points with an * indicate a significant difference from the control (Dunnett, P=0.05).



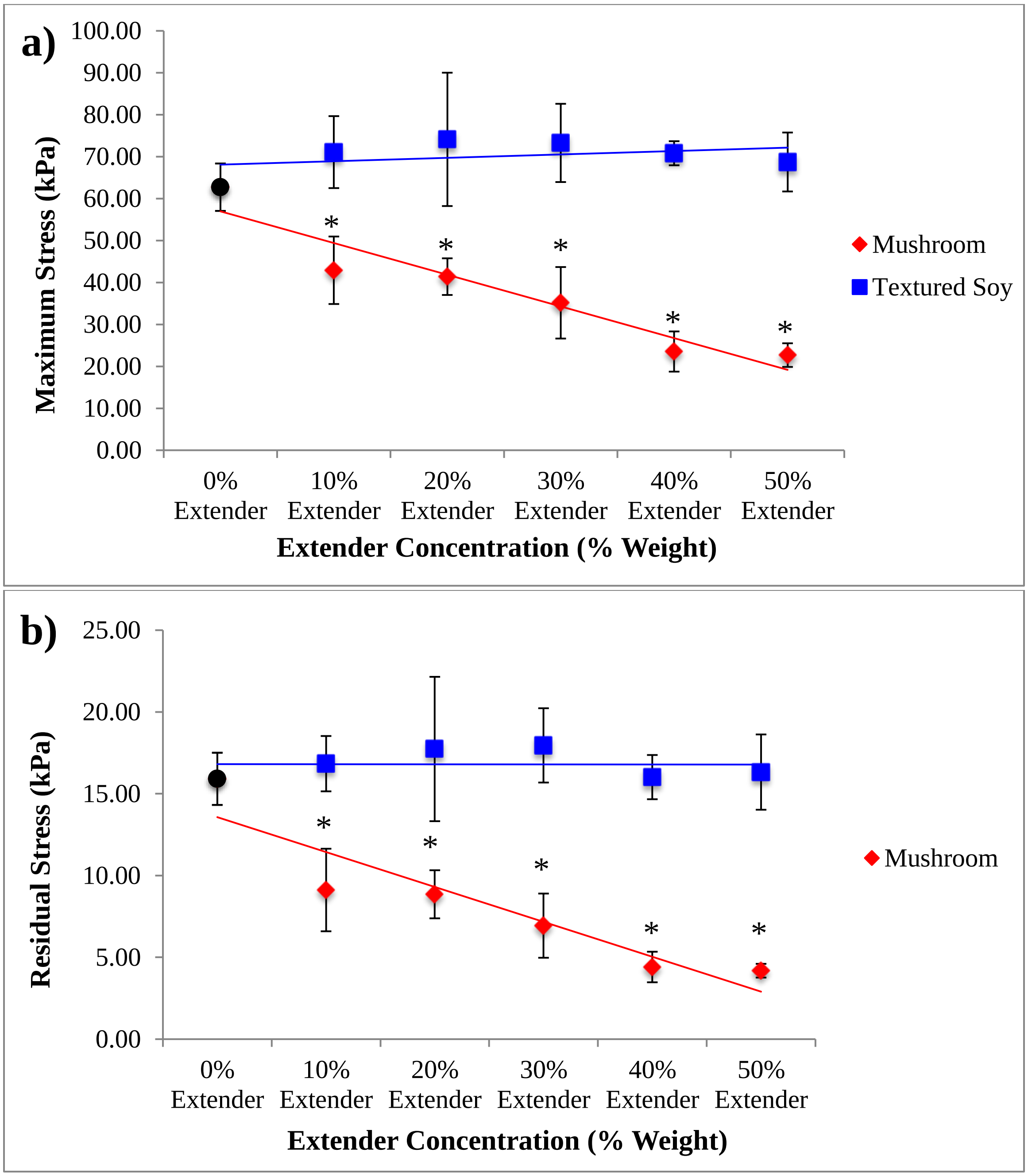
Cook yield results showed that altering meat extender concentration did not affect patty yield, however a statistically significant difference was identified among the formulations containing different meat extenders (Table 11). Figure 7 showed that in general, increasing mushroom concentration in burger patties caused cook yield to decrease and increasing TSP concentration cause cook yield to increase. Burger patties containing 50% mushroom had significantly lower yield than the all-meat control, while burger patties containing 30% TSP or more had significantly higher yield. This finding on mushroom supplemented patties could indicate that the water released from the mushrooms during cooking could not be entrapped within the patty, which could be supported by the significantly lower moisture retention of 50% mushroom patties identified in the moisture retention test. Similarly, the 50% TSP patties were identified to have higher moisture retention than the all-meat control, which could support this finding on TSP generally increasing cook yield.

Figure 8. Effect of meat extender type (mushroom or textured soy) and meat extender concentration on yellow color (b*). Note: The black circle is set at the all-meat control (0% extender). Data points with an * indicate a significant difference from the control (Dunnett, P=0.05).



Although meat extender type and meat extender concentration did not significantly affect lightness (L*) and red color (a*), both variables were shown to have a significant affect on yellow color (b*) (Table 11). Figure 8 showed the effect each meat extender had on patty yellow color. The addition of mushroom to patties at concentrations as low as 10% by weight significantly increased yellow color when compared to the all-meat control, while yellow color remained constant at all levels of TSP concentration. Although TSP would seem more advantageous than mushroom in burger patties because it kept yellow color statistically similar to the all-meat control, further sensory analysis was required to identify if this difference detected by an analytical method would translate into a difference deemed important by consumers.

Figure 9. Effect of meat extender type (mushroom or textured soy) and meat extender concentration on a) maximum stress and b) residual stress. Note: The black circle is set at the all-meat control (0% extender). Data points with an * indicate a significant difference from the control (Dunnett, P=0.05).



Meat extender type and concentration were also found to have significant effects on both maximum stress and residual stress (Table 11). Figure 9a and 9b showed how the addition of mushroom at any concentration significantly influenced patty texture while the addition of TSP kept patty texture similar to the all-meat control. Mushroom concentration at 10% by weight and higher were shown to have significantly lower maximum and residual stress compared to the all-meat control. Similar to yellow color, although TSP seemed more advantageous than mushroom because it produced patties with similar texture to the all-meat control from an analytical perspective, further sensory testing was required to identify if these similarities or differences would be important in influencing acceptability from a consumer perspective.

Table 12. Sodium and overall fat content in addition to the percent of sodium and overall fat reduction compared to the all-meat control for variant formulations with different meat extender types and concentrations. Note: All formulations with an * in bold indicate a significant difference from the control and quality for a “reduced sodium” or “reduced fat” claim (Dunnett, P=0.05).

Ground Beef (% Weight)	Meat Extender Type	Meat Extender (% Weight)	Sodium Content (mg Na+/g sample)	% Less Sodium than Control (%)	Overall Fat Content (% Weight)	% Less Fat than Control (%)
100	-	-	0.78	-	20.07	-
90	Mushroom	10	0.70	11.02	17.72	11.68
80	Mushroom	20	0.67	14.71	20.37	-1.50
70	Mushroom	30	0.60	23.15	20.12	-0.27
60	Mushroom	40	0.65	16.65	13.39	**33.29***
50	Mushroom	50	0.54	**30.45***	13.44	**33.02***
90	Textured Soy	10	0.79	-1.44	18.82	6.20
80	Textured Soy	20	0.65	17.12	13.71	**31.69***
70	Textured Soy	30	0.55	**29.56***	14.48	**27.82***
60	Textured Soy	40	0.49	**36.86***	13.38	**33.34***
50	Textured Soy	50	0.38	**51.19***	11.55	**42.46***

Mushrooms and TSP have lower sodium contents than ground beef (5 mg/100 g, 10 mg/100 g, and 66 mg/100 g respectively), which was reflected in the general decreases in sodium content of the patties with increasing meat extender concentration (USDA National Nutrient Database, 2016). Statistical analysis identified a difference in sodium content amongst formulations with varying meat extender concentration but not meat extender type (Table 11). Further analysis with the Dunnett's Test helped identify the concentration of each meat extender that significantly reduced sodium content compared to the all-meat control. Table 12 showed that mushroom did not significantly reduce sodium content until 50% concentration, while TSP began to reduce sodium content at 30% concentration. This finding suggests that TSP has a wider capacity to reduce sodium in burger patties than mushroom since it can do so at lower concentration levels even though it has higher sodium content than mushrooms (10 mg/100 g versus 5 mg/100 g respectively). Further research must be conducted on sodium retention in these mushroom and TSP extended burger patties to clarify these findings.

Mushrooms and TSP also have lower fat contents than 80/20 ground beef (0.34 g/100 g, 1.30 g/100 g, and 20 g/100 g respectively), which was reflected in the general decreases in fat content with increased meat extender supplementation (USDA National Nutrient Database, 2016). Similar to sodium content, statistical analysis identified difference in fat content amongst formulations with varying meat extender concentration but not meat extender type (Table 11). The Dunnett's Test detected significant differences in fat content between the all-meat control and variant formulations. Table 12 showed that mushroom began to significantly reduce fat at 40% concentration and higher while TSP began at 20% and higher. This finding suggests that TSP might also have a wider capacity to reduce fat in burger patties than mushroom since it can do so at lower concentrations even though it has higher fat content than mushrooms (1.3 g/100 g versus

0.34 g/100 g respectively). Statistical analysis did not show any variation in fat retention among the all-meat control and variant formulations regardless of meat extender type or concentration (Table 11). This finding suggests that mushrooms or textured soy in burger patties retains fat at a similar capacity to ground beef and may not be the reason behind TSP's wider fat reducing capacity compared to mushrooms regardless of its higher initial fat content. Further research must be conducted on fat uptake and retention in these mushroom and TSP extended burger patties to clarify these findings.

Overall, this set of physical characterization tests showed how mushroom and textured soy affect beef patties differently, but did not clarify which meat extender concentration results in patties most similar to the all-meat control. In general, increased mushroom concentration in patties resulted in increased moisture and yellow color, decreased rigidity, sodium content, and fat content, and similar yield, lightness, and red color in comparison to the all-meat control. Increased TSP concentration in patties in general resulted in increased yield, decreased sodium and fat content, and similar moisture, color, and texture to the all-meat control. However many of these findings applied to all of the formulations regardless of meat extender concentration, which made it difficult to identify a single concentration that performed most similar to the all-meat control. Concentrations of 10%, 20%, and 30% extender by weight were selected for further testing with sensory analysis to help identify an optimal concentration.

5.3.2 Hedonic Sensory Study Optimizing Meat Extender Concentration

The first of two hedonic sensory tests was conducted to identify the most liked concentration of each meat extender in addition to determine if changes in physical characteristics detected with analytical instruments would influence consumer acceptance. Patties were comprised of 80/20 ground beef, meat extender, and salt with the control formulation consisting of 98.5% meat, 0% meat extender, and 1.5% salt by weight. Variant formulations used 10%, 20%, or 30% IQF mushroom or TSP by weight. Meat blend and salt level were kept consistent throughout the all-meat control and variant formulations to solely look at the effects of varied meat extender concentration on consumer liking (Table 10).

Figure 10. Spider web plot showing the mean liking intensities of the sensory attributes for the fielded burger patty hedonic study identifying most liked meat extender concentration (Duncan's New Multiple Range Test, * = P=0.05, ** = P=0.01).

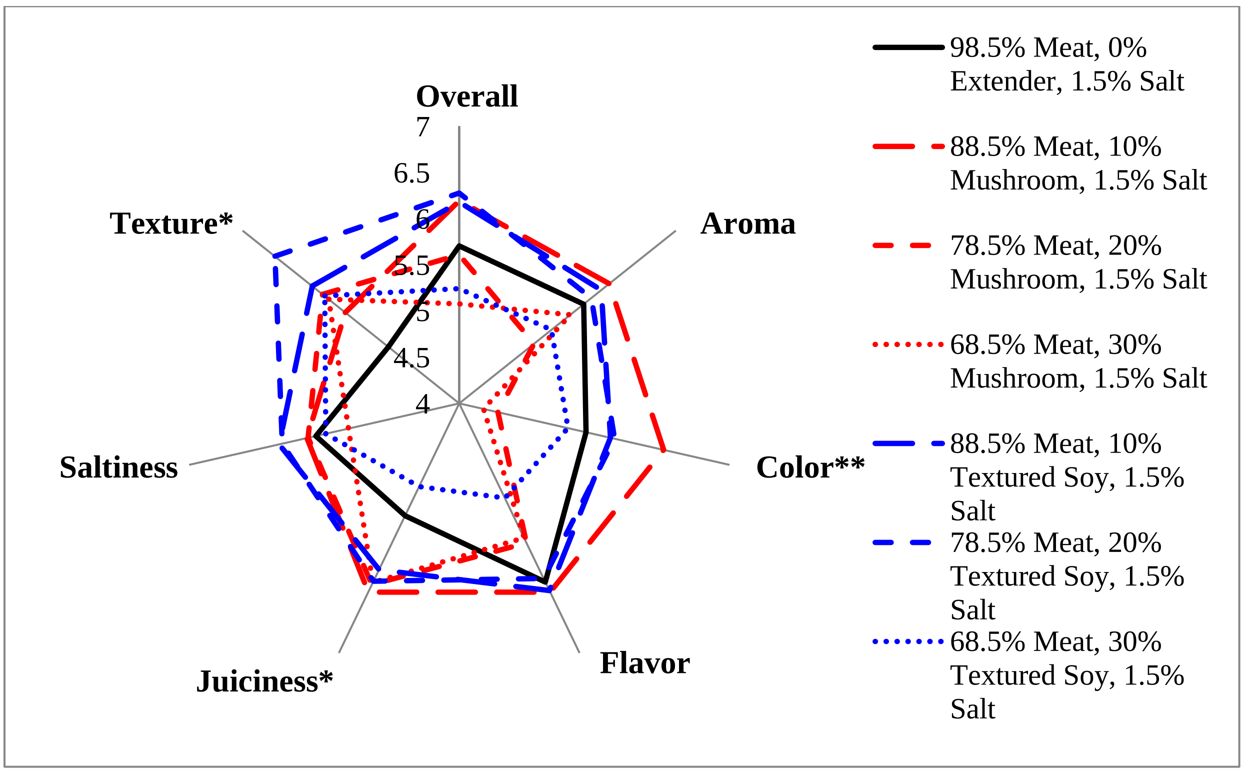


Table 13. Average liking values of the sensory attributes for the fielded burger patty hedonic study identifying most liked meat extender concentration. Values within a column with at least one similar letter label are statistically similar (Duncan's New Multiple Range Test, * = P=0.05, ** = P=0.01).

Formulation	Overall	Aroma	Color**	Flavor	Juiciness*	Saltiness	Texture*
98.5% Meat, 0% Extender, 1.5% Salt Control	5.70a	5.72a	5.41ab	6.15a	5.35ab	5.59a	4.98b
88.5% Meat, 10% Mushroom, 1.5% Salt	6.19a	6.08a	6.27a	6.27a	6.27a	5.69a	5.58ab
78.5% Meat, 20% Mushroom, 1.5% Salt	5.61a	5.04a	4.43bc	5.68a	6.18a	5.68a	5.89ab
68.5% Meat, 30% Mushroom, 1.5% Salt	5.08a	5.54a	4.27c	5.62a	6.15a	5.23a	5.81ab
88.5% Meat, 10% Textured Soy, 1.5% Salt	6.18a	5.96a	5.68a	6.25a	6.00a	6.00a	6.04ab
78.5% Meat, 20% Textured Soy, 1.5% Salt	6.28a	5.83a	5.72a	6.10a	6.14a	5.97a	6.55a
68.5% Meat, 30% Textured Soy, 1.5% Salt	5.24a	5.28a	5.21abc	5.14a	5.00b	5.48a	5.86ab

This hedonic sensory test used 55 untrained panelists to investigate the effects of meat extender type and concentration on consumer liking. Results from Figure 10 and Table 13 showed that the overall liking of variant formulations regardless of meat extender type or concentration were similar to the all-meat control. Variant formulation aroma, flavor, and saltiness liking was also statistically similar to the all-meat control. However, color, juiciness, and texture scores varied among the formulations with statistical difference demonstrated with an * or ** (Figure 10). Test subjects liked the color of the all-meat formulation similarly to 5 of the 6 variant formulations with the exception being the formulation containing 30% mushroom. This finding suggests that the differences in patty yellow color influenced by mushroom substitution (Figure 8) may also be affecting consumer liking. In general, liking scores decreased as mushroom concentration increased, while liking scores for TSP supplemented patties remained constant regardless of concentration. Although the ANOVA detected a significant difference in juiciness liking among the formulations, further analysis with the Duncan's New Multiple Range Test showed that all variant formulations were liked just as much as the all-meat control. Similarly, the ANOVA also detected a significant difference in texture liking among the formulations, but further analysis showed that the texture of the all-meat formulation was similarly liked to 5 of the 6 variant formulations with the exception being the formulation containing 20% TSP. This finding suggests that even though mushroom substitution significantly decreases patty rigidity (Figure 9a and 9b) it does not influence consumer liking. The juiciness and texture findings did not provide a consistent trend with meat extender type or concentration with consumer acceptance. The results from this test showed that consumers might equally like the all-meat control and a burger patty containing up to 30% mushroom or TSP, but might not like the color of the mushroom substituted patties as much. The 20% meat extender concentration was selected for further testing to maximize extender usage in the burger patties while imparting minimal differentiation from the all-meat control.

5.3.3 Hedonic Sensory Study of Reduced Sodium Patties

The second of the two hedonic sensory tests was conducted to evaluate the combined effect of meat extension and sodium reduction in burger patties on consumer acceptance when compared to an all-meat full sodium control. Again, patties were comprised of 80/20 ground beef, meat extender, and salt with the control formulation consisting of 98.5% meat, 0% meat extender, and 1.5% salt by weight. The “full sodium” level was set at 1.5% salt by weight, which was established in the previous hedonic sensory study. The “reduced sodium” level was calculated to have “25% less sodium per RACC than an appropriate reference food” to achieve a “reduced sodium” claim and was set at 1.1% salt by weight (U.S. Food and Drug Administration, 2013). All variant formulations used the reduced sodium level of salt while varying in meat extension: 0% extender, 20% mushroom, or 20% TSP (Table 10). Meat blend was kept consistent throughout the all-meat full sodium control and variant formulations to solely look at meat extenders’ potential mitigating effects of flavor loss in reduced sodium products.

Figure 11. Spider web plot showing the mean liking intensities of the sensory attributes for the fielded hedonic study on meat extension in reduced sodium burger patties (Duncan's New Multiple Range Test, * = P=0.05, ** = P=0.01).

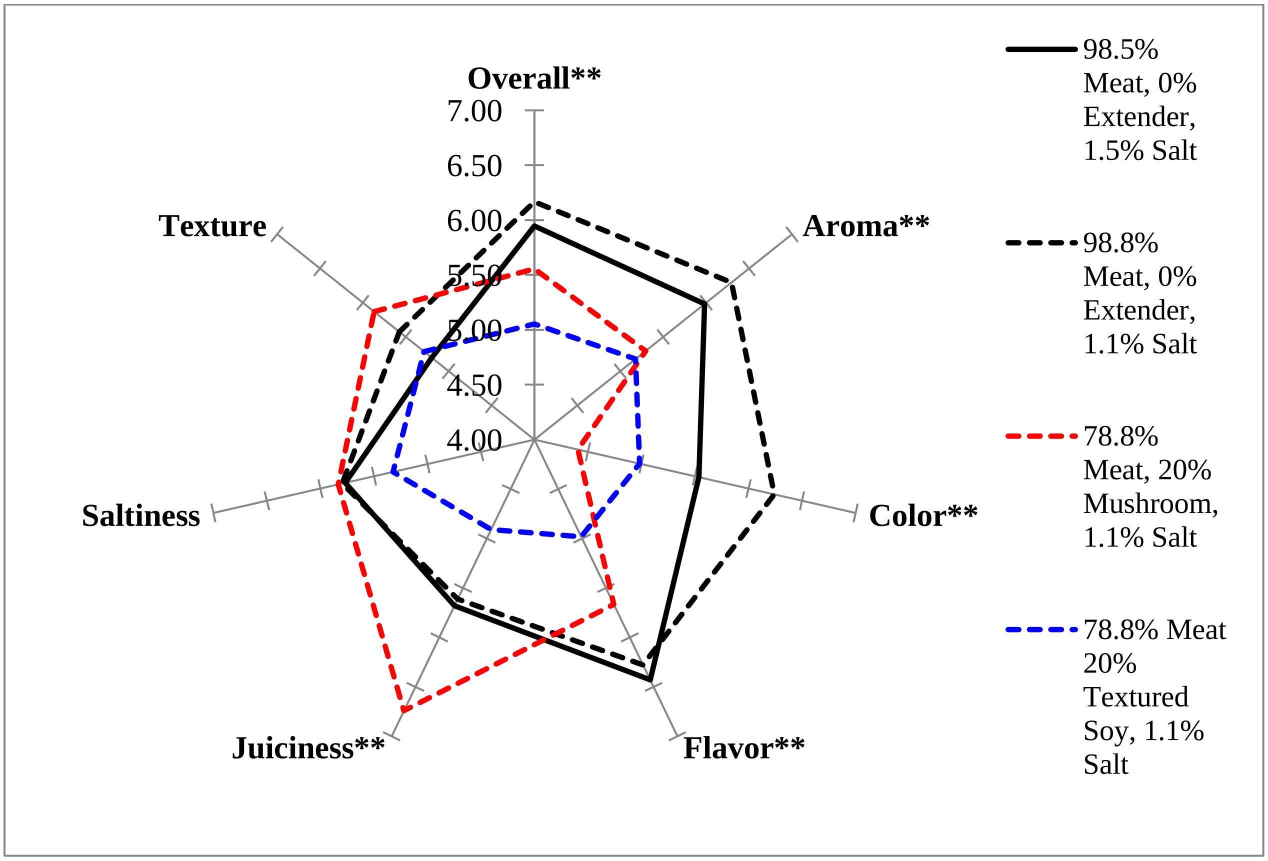


Table 14. Average liking of the sensory attributes for the fielded hedonic study on meat extension in reduced sodium burger patties. Values within a column with at least one similar letter label are statistically similar (Duncan's New Multiple Range Test, * = P=0.05, ** = P=0.01).

Formulation	Overall**	Aroma**	Color**	Flavor**	Juiciness**	Saltiness	Texture
98.5% Meat, 0% Extender, 1.5% Salt Control	5.95a	5.98a	5.54b	6.43a	5.68b	5.77a	5.20a
98.9% Meat, 0% Extender, 1.1% Salt	6.17a	6.30a	6.24a	6.28ab	5.61b	5.80a	5.57a
78.9% Meat, 20% Mushroom, 1.1% Salt	5.56ab	5.30b	4.41c	5.67bc	6.74a	5.83a	5.87a
78.9% Meat, 20% Textured	5.05b	5.18b	4.98bc	4.98c	4.91c	5.32a	5.29a

Soy, 1.1% Salt							

This hedonic sensory test used 56 untrained panelists to investigate the effects of meat extension and sodium reduction on consumer liking when compared to an all-meat full sodium control. Results from Figure 11 and Table 14 showed that overall liking of reduced sodium formulations containing 0% extender and 20% mushroom was similar to the all-meat full sodium control while the reduced sodium formulation containing 20% TSP was liked statistically less. This could be attributed to the differences in formulation liking across the other test attributes as detected by the statistical analysis. The only reduced sodium formulation to receive a similar aroma liking score to the all-meat full sodium control also contained 0% extender, while the 20% mushroom and 20% TSP formulations did not have as favorable aromas. The color of the reduced sodium 20% soy formulation was similarly liked to the all-meat full sodium control while the reduced sodium 20% mushroom formulation received significantly lower liking scores. Similar to the previous hedonic study, this finding suggests that the differences in patty yellow color due to mushroom substitution (Figure 8) may also influence consumer liking. Both reduced sodium meat extended formulations had less favorable flavor compared to the all-meat full sodium control and the reduced sodium formulation with no extender. However, the reduced sodium formulations with 0% extender and 20% mushrooms were similarly liked which might be contributing to their similar overall liking. The juiciness of the reduced sodium 20% mushroom formulation was most liked, followed by the two all-meat formulations, and the reduced sodium 20% TSP formulation was least liked. This finding suggests that the significant increase in moisture content due to mushroom substitution (Figure 6) might have a positive effect on consumer liking. Finally, variant formulation saltiness and texture like was statistically similar to the all-meat full sodium control. This texture finding was consistent with the previous hedonic study, which suggested that although mushroom substitution significantly decreased patty rigidity (Figure 9a and 9b) it did not influence consumer liking. The results from this test showed that consumers might equally like the all-meat full sodium control and a reduced sodium burger patty containing 0% or 20% mushroom, but again might not like the color of the mushroom substituted patties as much.

5.4 Conclusion

This research investigated the effects two types of meat extenders (IQF white button mushroom and textured soy protein) on meat extender concentration both physical characteristics of burger patties and consumer acceptance when used in reduced sodium applications. Physical characterization analysis showed how meat extension using mushrooms increased moisture and yellow color, decreased rigidity, sodium content, and fat content, and did not affect yield, lightness, and red color compared to an all-meat control. Analysis also showed how meat extension using TSP increased yield, decreased sodium and fat content, and did not affect moisture, color, and texture again when compared to an all-meat control. Hedonic sensory analysis showed that variation in meat extender type and meat extender concentration did not affect overall liking, aroma, flavor, saltiness, and texture liking scores in full sodium burger patties. However, meat extension using mushrooms yielded liking scores more similar to the all-meat formulations than TSP in reduced sodium applications. The findings from this research suggest that mushroom have the potential to be successfully incorporated into reduced sodium meat products to provide a healthier product.

CHAPTER 6

CONCLUSION

The first part of this research focused on understanding the effects of mushroom incorporation in taco filling applications on physical characteristics and consumer acceptance. Physical characterization analysis was used to investigate taco fillings with mushrooms at various particle sizes and concentrations with and without blanching in order to optimize mushrooms as an ingredient that can make the most sensory acceptable and healthiest meat products possible. Physical property assessments and sensory analysis concluded that up to 45% finely chopped (1 to 5 mm) of un-blanched, white button mushrooms can be integrated into a taco filling, which maximized mushroom usage while deemed equally liked to an all-meat control.

The second part of this research focused on understanding the sodium and fat reducing capacities of mushrooms in taco filling and its effects on consumer acceptance. Physical characterization analysis continued to investigate the effects of mushroom concentration while varying the level of added salt and varying the level of fat by altering the meat/fat blend of the ground beef. Physical property assessments concluded that varying salt and fat level did not impact a significant effect on taco filling, but demonstrated mushroom’s effectiveness at reducing overall taco filling fat content. Paired preference analysis showed that a reduced sodium taco filling containing 45% mushroom was more preferred by consumers than a full sodium taco filling containing 45% mushroom. However, a reduced fat taco filling containing 45% mushroom and leaner meat blend (90/10) was less preferred by untrained dining commons patrons than its full fat all-meat taco filling using 80/20 blend ground beef. This finding showed that the acceptance of mushroom in meat application could be influenced by meat blend.

The third and final part of this research focused on understanding mushroom usage in reduced sodium burger patty applications by comparing it to textured soy. Physical characterization analysis was used to investigate the physical changes of the patties caused by the different meat extenders as well as determine initial thresholds of meat extender inclusion with minimal difference against and all-meat control. Physical property assessments concluded that textured soy formulations had more similar characteristics to the all-meat control than mushroom formulations. However, hedonic sensory analysis showed that reduced sodium patties extended with mushrooms were similarly favorable to all-meat formulations than patties extended with textured soy. In conclusion, the findings from this research showed the promising potential of mushroom incorporation into meat products to improve health by lowering sodium and fat content while still maintaining consumer acceptance.

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